EQUATORIAL LAUNCH SITES

A STUDY



CLASSIFICATION CHANGE

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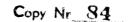
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PREPARED FOR

LAUNCH OPERATIONS CENTER
NASA

CHRYSLER CORPORATION SPACE DIVISION

HUNTSVILLE, ALABAMA

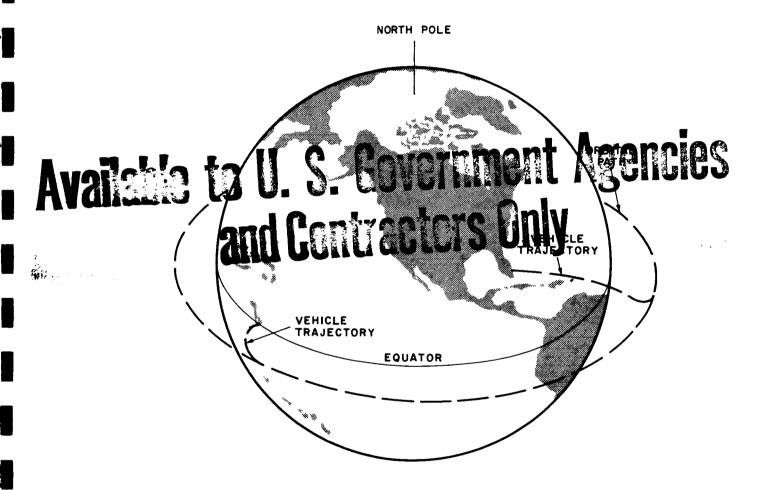


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26 JULY 1962



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FOREWORD

The study of equatorial launch sites presented herein is based on search of documentation. A comprehensive survey has been made, affording the reader a broader coverage of all principal aspects of the problems of equatorial launch than has hitherto been available. This study is to be regarded, however, as a necessary preliminary to exhaustive analysis of specific equatorial launch missions and their sites and attendant costs.

The overall plan of this study is indicated by the following array of its principal parts:

GENERAL INTRODUCTION

Part I -- TECHNICAL ASPECTS

Part II -- FACILITIES AND GENERAL COSTS

Part III -- POTENTIAL EQUATORIAL LAUNCH SITES

Part IV -- ABSTRACTS OF SELECTED EARLIER REPORTS

Appendix A -- MAPS OF TYPICAL ISLAND SITES

Detailed tables of contents appear at the beginning of Parts I, III, and IV.

This study has been prepared for the Launch Operations Center in accordance with Contract NAS 8 - 2849, Task Order LOD-CH-9.

GENERAL INTRODUCTION

I. LAUNCH SITE EVALUATION FACTORS

As the pace of our nation's space effort increases, it has become increasingly necessary to examine different concepts which could enhance our progress in space exploration. One such concept is the equatorial launch site.

It is the purpose of this report to present the basic arguments for and against the establishment of an equatorial launch site. The report was prepared after a thorough study of many independent earlier reports concerning this problem. As some of the program requirements have changed with technological advances, we have attempted to extract only the pertinent facts and to exclude the remainder.

A. Basic Types of Launch Site

The three basic types of proposed equatorial launch sites are: Mobile, Semi-Mobile, and Fixed launch sites. We will examine the advantages and disadvantages of each:

 The Mobile Launch Site. Such a site would consist of a ship or pair of ships that would function as a launching site for missiles and spacecraft.

a. Advantages.

- (1) A completely mobile launch site could select any point on the seas for a launch. Thus, it would not only be able to effect an equatorial launch, but launch over a wide range of latitudes, including a polar launch. In addition to increased mission capabilities, in case of an increase in international tensions, this mobility would enhance the chances of the site's survival.
- (2) Due to its mobility, such a site could effect a launch with a minimum of publicity. This would be in the national interest, presuming an alteration of the world political situation, as missions could be carried out with greater security than would be possible with a site having a fixed geographical position.

- (3) Any ship must contain certain equipment to aid in navigation and piloting. Range instrumentation installed into such a ship for the express purpose of tracking missiles (ie, air and sea radars) could also be employed for the ship's navigation.
- (4) A fully mobile launch site could respond quickly to unusual launch requirements, such as might be requested due to discovery of specific scientific data whose effects must be studied with minimum delay.
- (5) The mobility of such a site would allow cooperation with friendly powers in international space efforts.
- (6) Construction, repair, and modification of such a site could be accomplished in the United States in existing shippard facilities.
- (7) In the event of a sudden vehicle abort, such a site would have the additional safety capability of jettisoning the vehicle into deep sea water.

b. <u>Disadvantages</u>.

- (1) The living and working space aboard such a site would be limited, which might present a morale problem or a supply problem.
- (2) Ground Support Equipment (GSE) would have to be developed to meet a shipboard environment.
- (3) In the event of a major casualty (breakdown or damage), the replacement of damaged facilities would take a longer time.
- (4) In addition to the maintenance and repair of vehicle and general site facilities, there will also be maintenance and repair of that equipment specifically connected with shipboard, such as steam generators and turbines.
- (5) Due to the isolated environment of a ship and its relatively small size, the site would be more potentially hazardous than would be true with another form of site.
- 2. The Semi-Mobile Launch Site. Such a site would be a floating drydock arrangement. This could either be towed by a ship or anchored alongside a land site.

a. <u>Advantages</u>.

- (1) Although a semi-mobile site would have no motive power of its own, it could be towed by other craft, thus increasing its launching flexibility. In such a case, the site would be attended by at least one ship.
- (2) As with the mobile site, such a site could be constructed wholly within the United States. Such construction would not only allow employment of existing shippard facilities for construction, but would also avoid construction delay resulting from an unexpected lack of essential parts which would be available at short notice anywhere within the United States.
- (3) While GSE would have to be redesigned, due to the physical characteristics of the site, such modifications would be moderate.
- (4) If desired, the site could be repaired or modified in the United States.
- (5) A drydock lends itself to modification as a missile site. Due to the nature of drydock work, some instruments, such as cranes, are already available for use. Further, power facilities of a drydock will lend themselves to or can be adapted easily to the power requirements of a launch site.
- (6) A drydock launch site can anchor just off an island, and utilize the island for any part of its support. As an example, an island could be used for technical support, or it could be used as the settlement for the participating personnel. Since the drydock can anchor at any reasonable distance from the island, a measurable control of safety requirements would be afforded.
- (7) Studies suggest that the lead time for the construction of such a site is less than would be the case for a fixed base.
- (8) Since a drydock launching site is a fabricated construction, replacement launch complexes for new programs can be under construction in the United States while the existing complex is at sea, in action. Modifications could then be effected with much less lost time in any series of launch programs.

(9) As is true of the mobile launch site, the semi-mobile site would have provisions for a jettison capability for vehicle aborts. This, too, would be an additional safety parameter.

b. Disadvantages.

- (1) If the drydock site were to be utilized as a mobile unit (that is, at sea with adcompanying ships rather than at anchor near some island), all community, technical, and range support must be carried aboard the drydock or on the accompanying vessels.
- (2) As is true with a mobile site, in case of a major casualty, the replacement of damaged facilities would take a longer time.
- (3) It would be necessary to develop an integrated system of launch and range support if the drydock were to be utilized as a self-contained operation.
- 3. The Fixed Launch Site. This site could be either an island or a seacoast of a country that lies on or near the equator. Being land-based, it would of course be constructed on lines similar to existing facilities.

a. Advantages.

- (1) Since this would be a land-based operation, its operational concepts would be nearly identical to those in existing facilities. Additionally, it would allow the training of personnel at other sites (such as AMR and PMR), and rotation among these sites.
- (2) Since the construction, layout, etc. would be extremely similar to existing sites, the modification of existing GSE would be slight.
- (3) Proper choice of an island would allow erection of launch complexes with extensive supporting facilities. For example, a fabrication plant could be built to aid in the construction of needed parts without requiring transshipment from the United States, with its inherent time delay.
- (4) With an island, it is possible to construct a normal community for the personnel, including recreation areas. This would be a great aid to the morale of the personnel, and would be a factor in the personnel rotation rate.

- (5) Space would not be limited, in comparison to the mobile methods. This would allow flexibility in safety requirements and make certain design areas less critical.
- (6) Local labor and local industries could be used, if available, for the building of spacecraft and their component parts.

b. Disadvantages.

- (1) As the site would be fixed, it would have limited flexibility. It could not be moved for either technical or security reasons. The exit azimuth potential could not be altered.
- (2) The construction cost would be higher for this type of site than for the mobile sites. With the exception of possible raw materials, each unit of the complex would have to be shipped to the site. Modifications of the facility would have the same trouble.
- (3) The installation and checkout of the GSE would be much higher than the equivalent stateside installation for a mobile site.
- (4) Unless the island (or shoreline) to be used were owned by the United States, or under full U.S. control, the political approval of the country controlling the land would have to be obtained. With the site subject to political influences, it is possible that a radical political alteration could force abandonment of the site.

B. Site and Orbit Evaluation

There are several technical reasons why the establishment of an equatorial site may or may not be desirable. These fall into two broad categories: site reasons and orbit reasons.

1. <u>Site Reasons - Advantage</u>

a. An equatorial launch site could take distinct advantage of its location for certain types of orbits. This is specifically true of injection into low-altitude equatorial orbits. A vehicle would not only avoid the "dog-leg" maneuver to achieve an equatorial orbit, but the vehicle would have the advantage of the earth's maximum tangential velocity.

- b. As the transfer orbit from equatorial sites to equatorial orbits would be shorter, there is a potential saving from less fuel-oxidizer boil-off during the coasting period.
- c. An equatorial site would aid in the reduction of possible saturation of vehicles at present launch facilities.
- d. An equatorial site would be advantageous in any possible anti-satellite action, as a satellite orbit with an inclination must intersect the equatorial plane twice during each revolution.

2. Orbit Reasons - Advantages

- a. A substantial gain can be made in payload weight for low-altitude equatorial orbits. In addition, an orbit above the equator passes over precisely the same spots with each revolution, which is useful both in tracking and in rendezvous missions. Certain astronomical data, such as natural radiation levels and micrometeorite concentration, can be gathered from an equatorial orbit utilizing continuous tracking. Continuous monitoring would be both extremely difficult and extremely expensive if a space probe were in an inclined orbit.
- b. Recovery problems for space capsules would be vastly simplified by use of an equatorial orbit.

3. Site Reasons - Disadvantages

- a. There is an initial economic disadvantage in the construction of such a facility. Depending upon our space program goals, there may be a potential cost savings. The question arises as to whether or not these goals could be realized at the existing facilities at less total expenditure of money.
- b. There will be logistical disadvantages with any equatorial site. Vehicles, hardware, replacement parts, general supplies, and special project needs will for the most part have to be shipped to the site from the United States. Similarly, there may be a personnel problem as well, stemming from the relative isolation inherent in such a site.
- the establishment would be sensitive to the policital situation of the land on which the complex (or part) was constructed.

4. Orbit Reasons - Disadvantages

- a. With the exception of orbits below 1,000 nautical miles, injection can be made into an equatorial orbit with the "dog-leg" maneuver from present facilities, notably AMR, without undue payload loss. The higher the altitude of the orbit, the less the payload loss.
- b. Some missions cannot be effected with an equatorial orbit. While it is possible to launch a vehicle into a non-equatorial orbit from the equatorial launch site, little-if any-- net gain would be realized over launches from present facilities; in the case of a polar orbit launch, a net loss would be realized.

C. Trade-off Factors in Site Evaluation

If an equatorial site is required, certain considerations must be observed with regards to selection of a site. These would vary with the type of site to be employed.

If the site were to be a mobile one, or a semi-mobile one used as a self-contained site, the problem of site location would be relatively simple. One would merely choose a place with the required characteristics for any desired launching.

If, on the other hand, a land site or a semi-mobile site at anchor were desired, certain geographical and geopolitical data would have to be evaluated. One would have to evaluate such factors as climate (including rainfall, wind direction, storm frequency, and the like), geography (including position, area, flora, fauna, availability of water, etc), and the political situation. One would have to weight such factors as proximity to the United States versus an extremely favorable azimuth situation, or a political uncertainty versus an ideal climate. Stage fallout would also require consideration.

Until firm space programs have been established, it will be difficult to ascertain which is the ideal specific site.

Perhaps the most pertinent question as to the establishment of an equatorial site of any sort is that of its value in the country's overall space program. If it is high, establishing such a site would be well worth the effort; but if it would make only a marginal contribution to our overall program, then the additional expenditure of time and manpower could be employed more profitably at the present vehicle launching sites in an accelerated program using modifications, as necessary, to our present facilities.

There are specific types of missions that would be substantially enhanced by the use of an equatorial site. In particular, low-altitude equatorial orbits would realize a substantial gain in payload delivery by use of this type of site. It has been estimated that the following savings for the orbiting of 1,000,000 pounds into low-altitude parking orbits can be realized from an equatorial launch site instead of present facilities: time, one year; money \$685 million.*

For any mission requiring recovery, constant monitoring of orbiting vehicles, or rendezvous, especially in low-altitude equatorial orbits, an equatorial launch is a definite advantage.

There are, however, other missions and programs that an equatorial site will not benefit, and may actually hinder. Basically, these are (1) missions in which the orbit of the vehicle must be strongly inclined or (2) interplanetary missions.

A launch from an equatorial site into an inclined orbit will provide no gain over a launch from present facilities. Such missions as weather satellites, mapping satellites, monitoring and warning satellites, experimental navigation, and low-altitude communication satellites are examples. As such satellites have to scan (or must transmit to) regions of the earth beyond the effective horizon of a satellite at the same altitude in an equatorial orbit, it is necessary that such satellites have orbits of high inclination in order to function properly. This is also true of geophysical satellites concerned with gravitational or magnetic variations, whose measurements are of immensely greater value if determined from an inclined orbit.

Similarly, studies have indicated that for certain lunar and interplanetary missions, equatorial launches would be of no help whatsoever.

Such missions can be effected profitably from existing facilities. In such a case, the addition of an equatorial launch site would be no more than an added cost.

In conclusion, the basic question of the establishment of an equatorial launch site depends entirely upon the development of firm goals in our space effort, and an integrated and coordinated timetable of progress. If an equatorial launch site would materially enhance such goals, once established, then the necessity for its construction cannot be overemphasized. If not, the idea should be abandoned.

^{* &}quot;Saturn Systems Study" Classified, AOMC, 13 March 1959.

II. CONCLUSIONS

It is concluded that the establishment of an equatorial launch site cannot be economically justified on the strength of goals and objectives currently announced for the space programs of the National Aeronautics and Space Administration, regardless of the many advantages of such sites. This conclusion is drawn after a thorough study and analysis of all available information on the subject.

It is reasonable to assume that, with the definition of new and more advanced space programs, the requirement for the capability to launch space vehicles from the equator may later be justified. As new programs are established and as specific space missions are defined which may require an equatorial site, a more realistic evaluation can then be made as to its type and location.

Should there come a time when the establishment of a general-purpose equatorial launch site will be justified, it is concluded that a fixed, land-based site will provide the maximum net advantage.

Among all the sites considered in this study, the maximum net advantage is offered by Christmas Island, in the central Pacific Ocean.



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A. MAJOR SPACE VEHICLES

The major boosters and upper stages currently in use or proposed for space programs are listed in table I-1.

TABLE I-1
POTENTIAL VEHICLES FOR EQUATORIAL/MOBILE LAUNCHES

Boosters	Upper Stages
Advanced Saturn	Agena B
At1as	Atlas
Minuteman	Centaur
Nova	Delta
Polaris	Saturn S-IV
Redstone	Titan I & II
Saturn	
Scout	
Thor	
Titan II	

Brief descriptions of representative space craft appear below.

1. Atlas D

The Atlas D booster is a one-and-one-half stage vehicle powered by three liquid-rocket engines. Structurally, the vehicle is divided into the tankage and propulsion sections. The tankage section constitutes the forward portion of the air frame. This section of the booster consists of a central bulkhead to form the two propellant tanks. Pressure is maintained in the tanks to provide structural rigidity required to carry launch and flight loads. Two external pods are mounted on the aft section of the tank. These pods contain components of the flight control, radio-inertial guidance, propellant utilization, electrical, instrumentation, and range safety systems.

"Vehicle propulsion is provided by the use of a Rocketdyne MA-2 engine cluster consisting of two booster engines, one sustainer engine, and two vernier control engines. Propellants used are liquid oxygen and RP-1.

"All engines are gimballed by hydraulic actuators working in response to steering commands from the airborne flight control system to provide attitude control of the missile during flight. All five engines are ignited before liftoff. The booster engines provide thrust and directional control for approximately 130 seconds after launch.

Roll control during this period is the function of both booster and vernier engines. Shortly after booster engine cutoff, the engines with their associated structure and accessories are jettisoned, and propulsion and directional control are maintained by the sustainer and vernier engines. During this phase of powered flight, the vernier engines provide roll control and assist the sustainer in providing attitude control about the pitch and yaw axes. After sustainer engine cutoff, the vernier engines make final adjustments to the velocity vector during a 9.5 second nominal vernier solo period.

"A propellant utilization system is provided to control ratios of propellants remaining in the liquid oxygen and fuel tanks. Propellant level sensors in the liquid oxygen and fuel tanks provide information to a computer for the positioning of the liquid oxygen throttle valve in the sustainer engine." 1

2. Titan II

The Titan II, a two stage (tandem) vehicle, which uses storable liquid propellants in both stages. The fuel is an even mixture of unsymmetrical di-methyl hydrazine (UDMH) and N_2H_4 . The oxidizer is nitrogen tetroxide.

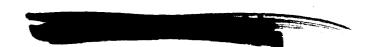
From a structural standpoint, the stages of this vehicle are each divided into two sections, tankage and propulsion. The tankage section, consisting of two separate, integrally stiffened propellant tanks joined by an intertank system, composes the forward portion of each stage. The all-inertial guidance system, as well as the flight control components, are contained in the second stage. The autopilot servo controls in both the stages are fed from these components. Roll and attitude control are accomplished by the gimballed engines in each stage. These gimballed engines are connected to the airborne flight control systems.

3. Centaur

"The Centaur vehicle consists of the following: liquid hydrogen and liquid oxygen propellant tanks; two 15,000 pound thrust main engines; two sets of hydrogen peroxide rockets for vernier and attitude control during coast periods; guidance and control system and associated systems: various electronic systems; and low-drag fairing which shields the payload and equipment mounting area.

"The Centaur thrust structure is attached to the aft bulkhead of the oxidizer tank and provides the mounting for the two main engines.

^{1 &}quot;Equatorial and Mobile Launch Operations and Facilities", Navy Department, 9 August 1961



"The overall length of the Centaur vehicle from the forward tip of the nose fairing to the aft end of the 15,000 pound thrust chambers is 42.5 feet with a tank diameter of 10 feet. This stage will weigh approximately 32,000 pounds at launch, including propellants and payload but excluding insulation panels and nose fairings. The CENTAUR air frame houses the main propellants and provides support integration for all second stage airborne systems as well as primary structural integrity. It consists of the forward, mid, and aft sections. These sections are covered separately in the succeeding paragraphs.

"The forward section includes the payload, guidance, electronic, and flight control system equipment packaging and associated supports or mounting structures. All are housed under the low-drag nose fairing which is fastened to the forward bulkhead of the main tank section.

"The mid-section includes the main propellant tanks on which are located the electrical fairings, conduits, antennas, ATLAS-CENTAUR separation fittings, fuel tank insulation, attitude rocket motors, and various other equipment mounting bracketry.

"The aft section consists of the main engine and boost pump support structure; the pneumatic control system, storage bottles, and associated plumbing; the monopropellant storage tanks; the hydraulic actuators; and other associated equipment and mounting structure. This section, which is enclosed by the adapter section during first-stage flight, is referred to as the second-stage engine compartment."²

4. Scout-Class Vehicle

The NASA Scout vehicle and its counterpart, the Air Force Scout, are existing developed vehicles with a modest space-probe and satellite capability. For example, the configurations shown in Table I-2 weigh 35,815 pounds and will lift a 340 pound payload into a 300 nautical mile circular orbit.

"Scout vehicles are readily adapted to shipboard launch. Because of their extreme simplicity, they could easily be launched from any of the sites discussed in this report without requiring any expensive modification or addition of equipment."

5. Medium Size Vehicles

"Numerous combinations of medium size four and five stage solid propellant vehicles have been analyzed. The major components used

² "Equatorial and Mobile Launch Operations and Facilities", Navy Department, 9 August 1961

³ IBID

TABLE 1-2 MEDIUM CLASS VEHICLE SUMMARY

•										
Maximum Payload (300 N.M.)	80	340	175	350	450	945	1510	1460	1430	1970
Maximum Diameter (In.)	31	70	54	54	54	65.5	65.5	65.5	65.5	100
Overall Height (Avg)	41'-4"	72'-7"	32'-4"	33'-4"	42'-0"	51'-8"	69'-10"	67'-0"	66'-10"	83'-8"
Overall Weight (Avg)	12,440	35,815	31,825	37,420	40,245	65,860	91,497	92,064	90,452	197,495
Identification	Scout F2	Scout F5	Polaris-Scout Combination	Polaris-Scout Combination	Polaris-Scout Combination (Sea Scout)	Minuteman Combination	Minuteman-Polaris-Scout Combination	Minuteman-Polaris Combination	Minuteman-Polaris-Scout Combination	Booster "X" Minuteman- Polaris Combination
Combination Number	1	7	m	4	ſΩ	9	7	∞	σ	10

are generally the existing Minuteman (MM) motors, Perishing (P), and Scout Motors. Typical performances for 100,000 pound four-stage MM-MM-PP configurations are 500 to 1000 pounds in a polar 300 nautical mile orbit and 250 pounds in a 6000 nautical mile orbit.

"These vehicles are larger than the Scout, and would require special handling and erection equipment. The necessary equipment would be easily added to the fixed site, and could probably be added to the semi-mobile drydock. At somewhat greater, but still moderate expense, the ATLAS-CENTAUR launch equipment on the mobile ship could be removed and replaced by the necessary equipment. With care in design, it should even be possible to shift alternately back and forth between ATLAS-CENTAUR and MINUTEMAN as desired with only moderate conversion time."

6. Saturn C-1

The Saturn C-1 consists of four basic parts:

- a. <u>S-I Stage</u>. The S-I stage of the SATURN C-1 launch vehicle is formed by the clustering of nine propellant containers. The tanks contain liquid oxygen in a center 105-inch container and RP-1 fuel and LOX in alternate 70-inch outer containers. The stage is powered by eight H-1 engines, each producing 188,000 pounds of thrust at sea level. Four of the eight engines are capable of being gimballed 10° and are used for control and initiating path changes upon command of the guidance computer located forward of the S-IV stage.
- b. <u>S-IV Stage</u>. The second stage (S-IV) of the vehicle uses A-3 liquid hydrogen and liquid oxygen as propellants. Six RL10A-3 engines, each of 15,000 pounds of thrust, power the second stage; and all six are gimballed for control.
- c. <u>Guidance and Payload Adapter Section</u>. This is a 154-inch diameter wafer located above the S-IV, adapting the payload to the vehicle and housing the vehicle guidance, control, and necessary associated equipment.
- d. <u>Payload</u>. The payload varies with the type of mission to be performed. Greater payloads can be placed into low altitude parking orbits.

7. Saturn C-5

"Manned lunar circumnavigation and manned lunar landings will utilize Saturn C-5, the development of which has recently been authorized.

4 IBID

"Saturn C-5 will be 396 inches in diameter and about 350 feet long. Its takeoff weight will be slightly over 6 million pounds. To lift this enormous weight off the ground the Saturn C-5 first stage will be powered by five kerosene-oxygen F-1 engines giving a total thrust of 7.5 million pounds. The second stage will be powered by five J-2 liquid-oxygen-liquid-hydrogen engines producing a total thrust of one million pounds. For orbital missions, a two-stage version of the C-5 would normally be used, while for escape missions a third hydrogen-oxygen stage powered by a single J-2 may be added to increase the payload. Saturn C-5 will be able to place well over 200,000 pounds into a 300 n. mile orbit and to project at least 85,000 lb into an earth-escape trajectory."5

B. VEHICLE PERFORMANCE DATA

A performance comparison of the Atlas D, Titan II, and Saturn C-1 vehicles appears in figure I-1.

C. GEOPHYSICAL EFFECTS OF EQUATORIAL LAUNCH

The variation in the earth's gravitational acceleration with latitude and elevation is presented in Figure I-2. This datum was taken from Operation And Calibration Manual For Saturn S-1 Propellant Monitoring System, LOD, and illustrates the physical advantage of locating a launch site on the equator and at as high an elevation as possible. Figure I-3 presents the change in earth's tangential velocity with latitude, and Figure I-4 shows the loss of tangential velocity as the latitude is increased from the equator. A velocity penalty of 180 feet per second exists between Cape Canaveral (AMR) and the equator, and 275 feet per second between the Pacific Missile Range (PMR) and the equator.

Figure I-5 shows the variation of total rotational energy per unit mass at sea level with latitude. Figure I-6 presents the variation in weight per pound as the latitude is increased from the equator. The weight decrease, ΔW , is 0.10 per cent per pound between the AMR and the Equator. This figure in itself looks very insignificant but when the enormous weight of the ADVANCED SATURN series of spacecraft is considered, the weight reduction at the Equator over the AMR would approximately be 5,000 pounds. This means that 5,000 pounds could be added to the take-off weight if it were properly distributed in fuel and payload weight. The proper thrust-to-weight ratio must be maintained, which means that the added weight must be distributed in fuel and payload to all stages except the booster. This would indicate that the optimum missile for equatorial launches into low altitude circular parking orbits would be a single stage booster capable of placing the entire upper stages plus payload into orbit. The increased weight in fuel and payload would

⁵ "Astronautics", Page 5, February 1962

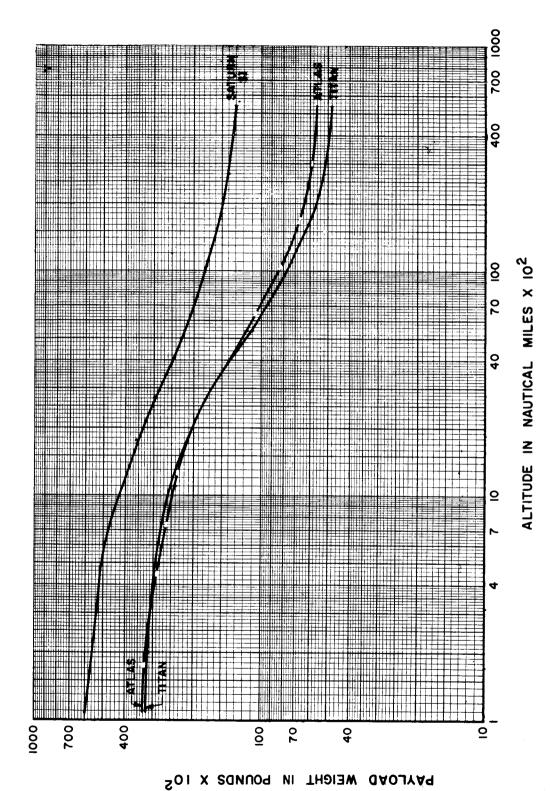


FIG. I-1: PERFORMANCE CAPABILITY COMPARISON

ACCELERATION OF GRAVITY (FEET PER SECOND SQ.)

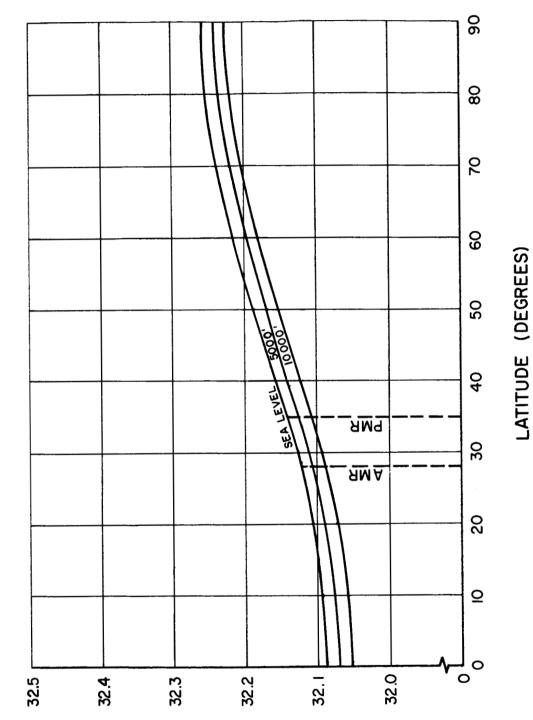


FIG. I-2: VARIATION OF EARTH'S GRAVITY WITH LATITUDE AND ELEVATION

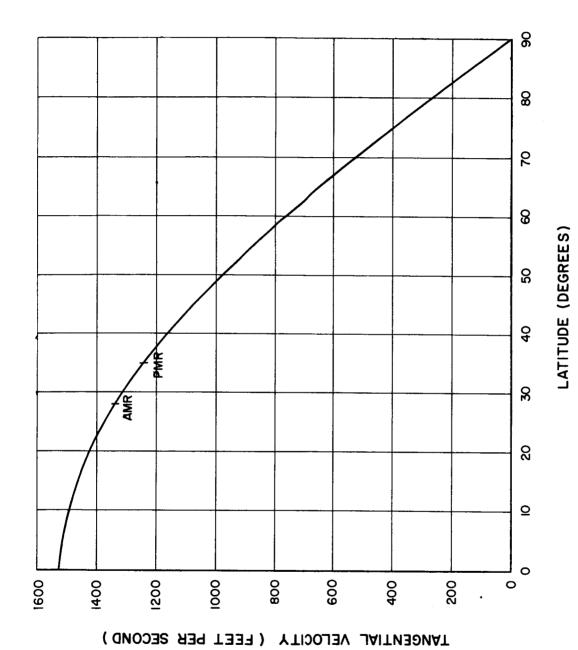


FIG. I-3: VARIATION OF THE EARTH'S TANGENTIAL VELOCITY WITH LATITUDE

FIG. I-4: LOSS OF TANCENTIAL VELOCITY WITH LATITUDE

TANGENTIAL VELOCITY VARIATION (FEET PER SECOND)

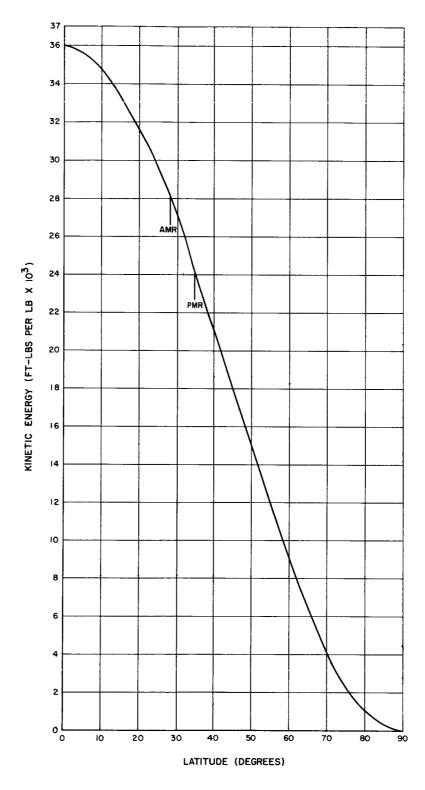


FIG. I-5: VARIATION OF ROTATIONAL ENERGY PER UNIT MASS WITH LATITUDE AT SEA LEVEL

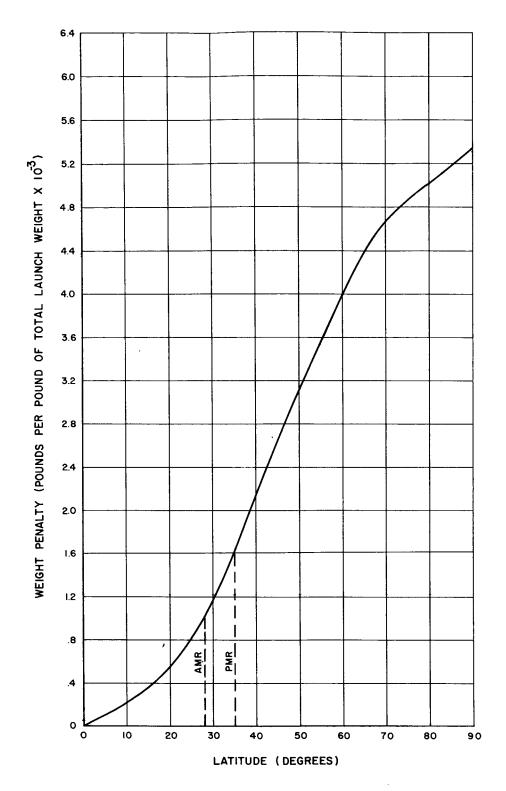


FIG. I-6: VARIATION IN WEIGHT WITH LATITUDE DUE TO EARTH'S GRAVITATIONAL CHANGE AT SEA LEVEL

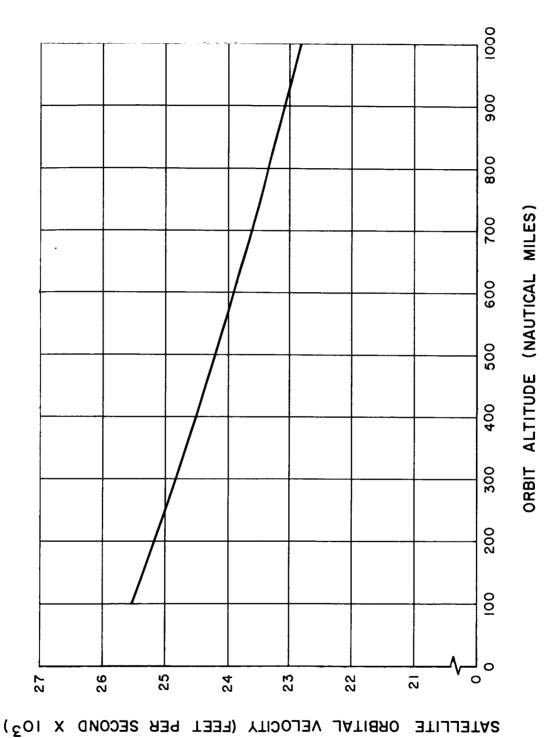
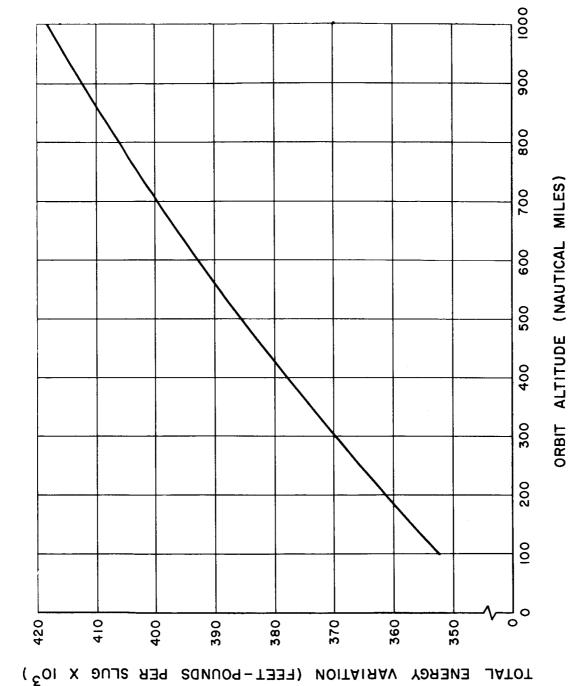
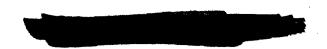


FIG. I-7: THE VELOCITY VARIATION FOR CIRCULAR EARTH ORBITS



THE VARIATION IN TOTAL ORBITAL ENERGY PER UNIT MASS BETWEEN DUE EAST LAUNCHES FROM THE AMR AND THE EQUATOR FIG. I-8:



require modification of the guidance program for existing missiles to allow for the increased burning time and increased range to orbital injection.

Figure I-7 shows the required velocity to place a satellite of unit mass into a circular earth orbit at the various altitudes indicated. Figure I-8 shows the difference in total energy required to place a unit mass into a circular orbit about the earth, at the Equator, and the AMR. If identical payloads in identical missiles are to be launched due east in azimuth from the equator and the AMR, it is possible to obtain greater orbital altitudes from the equator because of the earth's greater rotational energy there.

D. TRAJECTORY ANALYSIS-ADVANCES SATURN CLASS VEHICLE

A space vehicle of the advanced Saturn class was programmed into Chrysler's high speed digital computer in order to conduct a trajectory analysis of low-altitude circular parking orbits when launched due east from the AMR and the equator. Table I-3 illustrates the performance parameters for this vehicle.

Trajectory analyses were conducted on the digital computer to determine the difference in burning time for identical missiles launched due east from the AMR and the equator into 100, 300, 500 and 700 nautical mile circular orbits. The trajectories were almost identical in profile for the AMR and equatorial launches. Therefore only the AMR trajectories were presented in Figure 9, a and b. The amount of difference in second stage burning time accounted for the weight gained in orbit at the equator due to the unused fuel in the second stage. Table I-4, a and b, presents these trajectory data for the 100 nautical mile circular orbit for both AMR and equatorial launches.

It must be noted that the trajectories were not the optimum ones from a weight standpoint as the time available to conduct the program was insufficient to allow for this optimization. Hence, the trajectories presented were ones that would reach each orbital altitude with a zero lift turn into the orbit. Coasting was necessary for all trajectories. The coast time was initiated after first stage separation for the 100 and 300 nautical mile orbits. The 500 and 700 nautical mile orbits were obtained by firing the second stage after first stage separation and then allowing for a coast period during the second stage flight. The second stage was restarted and injected into orbit with the programmed zero-lift turn.

The total weight of the second stage structures plus fuel (if any) plus payload is placed into orbit. This total weight variation with orbital altitude is illustrated in Figure I-10 for the AMR and the equatorial launches. This amounts to 2341 pounds gained from the equatorial launch for a 100 nautical mile orbit. This is only a gain of 0.86 percent as shown in Figure I-11. Although this is a very small percentage gain it does illustrate the gain available due to the greater





TABLE I-3. ADVANCED SATURN CLASS VEHICLE

(A two stage spacecraft was used in the Philco 2000 Digital Computer Program. The first stage cutoff and separation occurred at 164 sec for all eight trajectories. A zero lift trajectory was used throughout the program.)

<u>Parameter</u>	First Stage	Second Stage
Base Area	704.53 Feet ²	367.18 Feet ²
Exit Area	374.87 Feet ²	120.02 Feet ²
Initial Weight	4,800,796.5 Pounds	806,353.06 Pounds
Final Weight	1,079,137.69 Pounds	(Variable)
Burning Time	164.65 Seconds	(Variable)
Burning Rate	22579.3 Pounds/sec.	2254.26 Pounds/sec.
Vacuum Thrust	6,787,739.7 Pounds	962,740.93 Pounds
Sea Level Thrust	5,994,173.87 Pounds	664,288.0 Pounds
Specific Impulse (Vacuum)	300.2965 Seconds	427.0763 Seconds
Specific Impulse (Sea Level)	265.1884 Seconds	294.6812 Seconds
Thrust/Weight Ratio	1.2486	0.8238 Seconds

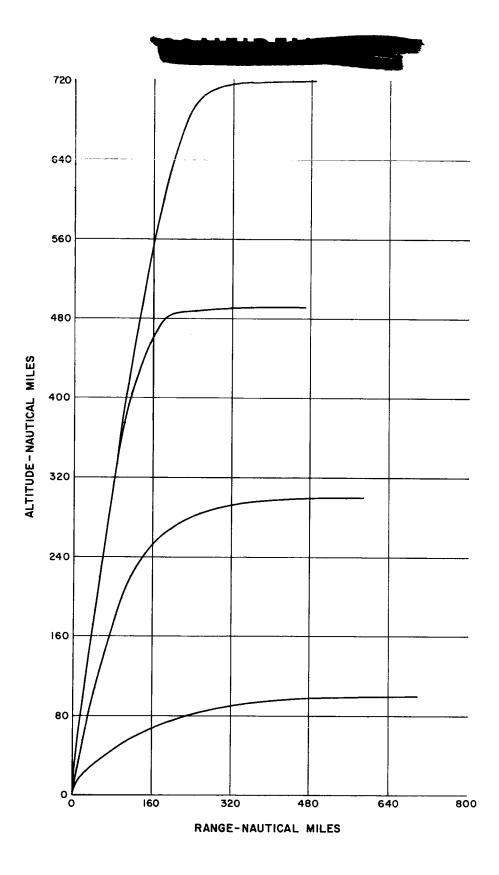
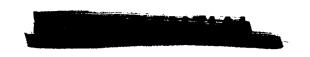
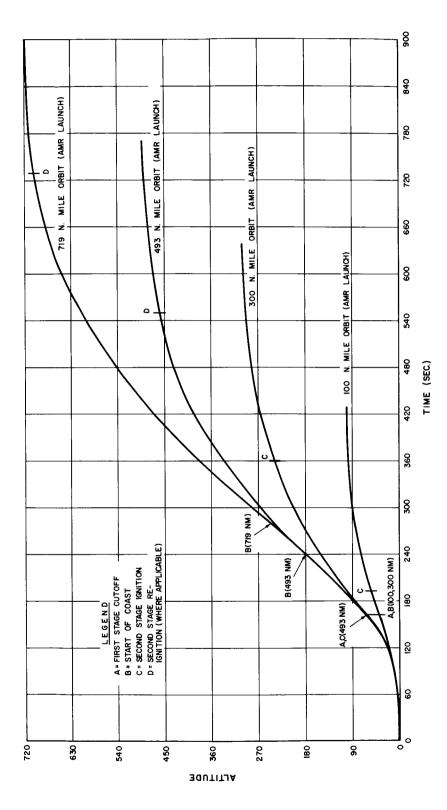


FIG. I-9a: VARIATION OF ALTITUDE WITH RANGE FOR DUE EAST LAUNCHES FROM THE AMR AND THE EQUATOR





VARIATION OF ALTITUDE WITH TIME FOR DUE EAST LAUNCHES FROM THE ARM AND THE EQUATOR FIG. I-9b:

Rema rks	Cutoff let stage separation and coast End of coast 2nd stage ignit:on Orbit
Weight (pounds)	4,800,796,56 4,574,762.01 4,348,727,46 3,941,865.27 3,941,865.27 1,952,761.23 1,079,1727.07 1,079,133.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06 806,353.06
Vertical Accel. ft/sec ²	8 .084 10 .1456 12 .589 17 .459 20 .472 21 .194 . 22 .792 36 .792 36 .792 36 .792 36 .792 36 .792 36 .792 36 .792 44 .988 -25 .685 -25 .685 -25 .482 -14 .541 -14 .968 -13 .524 -8 .195 -6 .963 -6 .96
Horiz. Accel. ft/sec ²	0 - 0440 - 0949 8 045 19.068 40.080 96.855 163.142 185.817 - 3.219 - 2.922 33.426 44.232 58.808 83.576 92.867 111.084
Dynamic Pressure lbs/ft ³	0 469 469 469 469 469 471.376 471.34 643.76 6.50 6.50 6.50 6.50 6.50 6.50 6.50 6.5
Mach No.	0 0.0815 0.184 0.184 0.795 1.624 1.624 11.044 11.080 10.543 7.955 5.848 6.228 6.228 6.228 7.894 8.451 9.071
Phi deg	0
Velocity ft/sec.	90.858 90.858 47.250 831.234 1572.22 4838 083 8644.37 10,174.63 9988.740 9888.740 9888.740 10,456.98 12,253.68 15,456.98 15,456.98 15,456.98 15,456.98 15,456.98 15,456.98 15,456.98 15,456.98
Altitude N Mile	0 0 0 1 1 2 9 1 2 9 2 2 1 2 9 2 2 1 2 9 2 2 1 6 9 4 2 2 3 3 9 4 1 7 4 9 2 5 3 9 9 6 5 0 100 0 0 2 100 1 1 8 1 1 0 0 1 1 8 1 1 0 0 1 1 8 1 1 0 0 1 1 8 1 1 0 0 1 1 8 1 1 0 0 1 1 8 1 1 0 0 1 1 1 1
Range N Mile	0 -0.000117 -0.000967 0.4825 2.8077 21.462 53.677 63.737 91.549 91.549 1108.173 1108.173 136.709 222.492 363.114 542.917 652.307 682.170
Time (sec)	0 20 38 38 54 78 1126 1158 1164.6 1193.4 1193.4 1193.4 221.4 221.4 229.4 323.4 323.4 420.5 427.46

r Orbit	
e Circular	MR
utical Mil	ed from A
100 Nautical	Launched
Table I-4b:	

Remarks	Cutoff 1st stage separation and coast End of coast 2nd stage ignition
Weight (pounds)	4,800,796,56 4,574,762.01 4,348,727.46 3,941,865.27 3,676,071.79 1,952,761.23 1,229,450.67 1,229,450.67 1,729,137.69 806,353.06
Vert. Accel. ft/sec ²	10. 201 12. 646 17. 505 20. 475 21. 176 21. 474 22. 868 37. 282 44. 668 -25. 63 -25. 63 -25. 573 -14. 562 -14. 798 -15. 015 -15. 015 -15. 015 -15. 015 -15. 015 -16. 010 -17. 0009
Horiz. Accel. ft/sec ²	0392 0845 -8. 123 19. 173 40. 909 58. 015 96. 944 162. 559 186. 034 -3. 680 -3. 165 -2. 910 33. 894 36. 415 44. 216 58. 787 83. 558 92. 854 104. 302 111. 082
Dynamic Pressure lbs/ft ³	0 47.36 215.42 473.86 644.16 97.58 97.58 12.52 6.50 6.50 0 0 0 0
Mach No.	0 0.0820 0.1851 0.7981 1.6298 2.501 4.574 8.985 11.058 11.058 11.058 11.058 11.058 11.700 10.700 10.700 8.200 8.200 8.200 8.444 7.902 8.458 9.078 9.078
Phi deg	0. 12006 0. 2245 9. 3918 20. 211 37. 897 47. 8870 61. 680 68. 765 69. 631 72. 047 73. 343 73. 343 75. 756 89. 977 89. 962 89. 962
Velocity ft/sec.	0 205.296 479.39 834.50 1577.88 2451.05 4846.75 8916.50 10, 185.55 10, 000.92 9, 913.70 9, 913.70 112, 275.67 112, 275.67 112, 275.67 113, 275.67
Altitude N Mile	0 0.7236 0.31301 1.29798 2.93962 6.9654 10.78114 21.0934 35.5589 39.4269 39.4269 49.2372 53.8231 53.8231 61.8455 79.3647 93.9617 99.9835 100.115
Range N Miles	0 000104 00086 0 0.05381 0.48850 2.88918 6.4858 21.5445 53.8210 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 63.8959 64.895 220.7875 680.966 692.758
Time (sec.)	0 10 20 38 38 54 78 78 94 126 158 164, 6 164, 6 192, 06 192, 06 210, 06 258, 06 322, 06 322, 06 402, 06 402, 06 418, 06 426, 06 426, 06



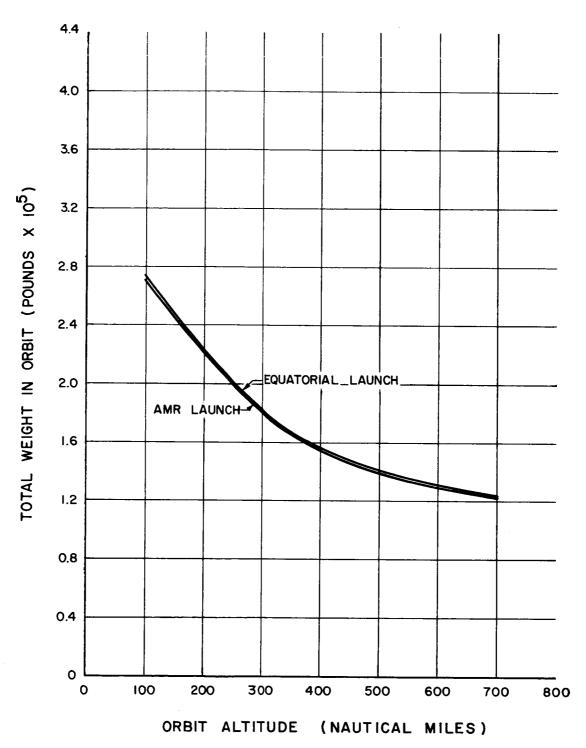
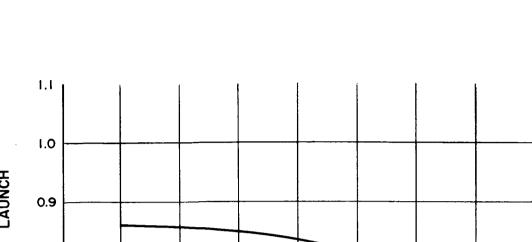
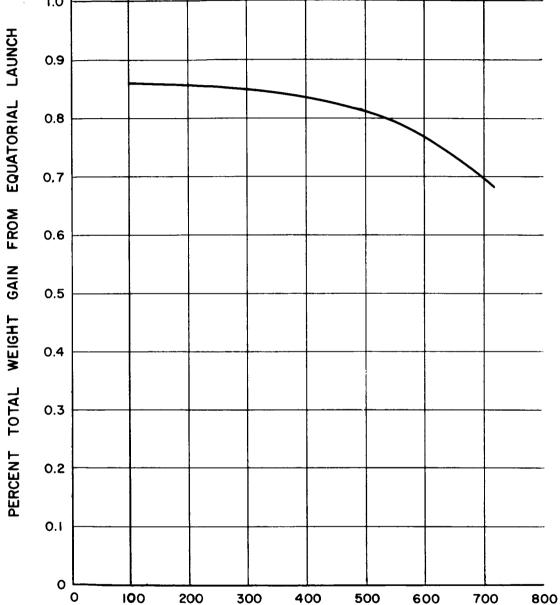


FIG. I-10: TOTAL WEIGHT IN ORBIT RESULTING FROM DUE EAST LAUNCHINGS FROM THE AMR AND THE EQUATOR





ORBIT ALTITUDE (NAUTICAL MILES)

FIG. 1-11: PERCENT GAIN OF TOTAL WEIGHT IN ORBIT RESULTING FROM THE COMPUTER PROGRAM STUDY

initial rotational energy available at the equator. The magnitude of the total weight gained in orbit could have been increased if the proper weight optimization program had been conducted on the digital computer.

E. DOG-LEG MANEUVER INTO EQUATORIAL ORBITS

The performance penalty for turning the plane of an orbit during boost or at injection, often called a "dog-leg" maneuver (Figure I-12), is conveniently expressed in terms of a velocity increment $\triangle V_T$, which is the extra velocity required for the propulsion system for the "dog-leg" maneuver as compared to a purely planar boost and injection into orbit.

"In general $\triangle v_T$ increases approximately as the square of the turning angle required. It decreases rapidly with increasing altitude for circular satellite orbits. For elliptical orbits such as the transfer from a low altitude parking orbit to a 24-hour circular orbit, the turn should be made at apogee, where the velocity is minimum." 6

Calculations were made of the weight of fuel required to establish circular equatorial orbits from the AMR at 100, 300, 500, 700, 1000, 2000, 20,000 and 207,000 nautical miles in altitude. The last two altitudes are the 24-hour orbit and a lunar orbit, respectively. The total velocity penalty $\Delta V_{\rm T}$ required for a two-impulse transfer at apogee from the launch plane into the equatorial plane for the preceding altitudes is shown in Figure I-13. This data was taken from Reference 2 and includes the effects of the earth's rotation which contributes 1,520 feet per second at the equator and 1,340 feet per second at the AMR for due east launches.

Figure I-14 presents the variation of total weight in orbit with altitude which results from an AMR launch and "dog-legging" into the equatorial plane. Figure I-15 presents the variation in total weight in orbit with latitude for a 300 nautical mile, a 2000 nautical mile, and a 24-hour synchronous orbit. The greatest benefit to the amount of total weight in orbit can be obtained for the low altitude equatorial orbits.

Figure I-16 illustrates the per cent gain in total orbital weight resulting from an equatorial launch. These results indicate a gain of 58 per cent for the 100 nautical mile orbit, 14 per cent for the 24-hour orbit and only 5 per cent for lunar orbits for vehicles of the Advanced Saturn Class.

Table I-5 summarizes the weight breakdown for four selected vehicles which were used in the ABMA Report. This table gives lift-off and cut-off weights, thrust levels, specific impulses, flight performance, propellant reserves, and typical payloads for three missions: 96 minute circular orbit (300 n. mile), 24-hour circular orbit, and escape trajectory.

⁶ "Equatorial and Mobile Launch Operations and Facilities", Navy Department, 9 August 1961.

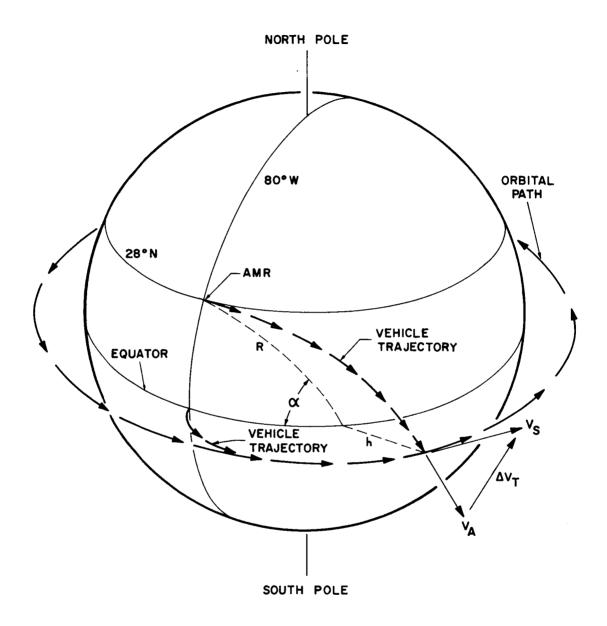


FIG. I-12: APOGEE TRANSFER INTO EQUATORIAL ORBIT FROM THE AMR

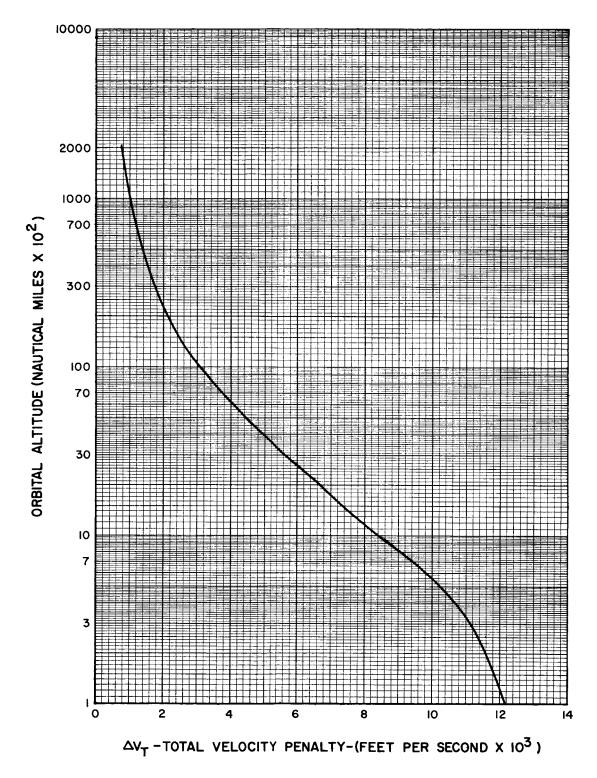
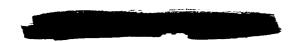


FIG. I-13: TOTAL VELOCITY PENALTY RESULTING FROM AN AMR LAUNCH WITH A "DOG-LEG" MANEUVER INTO THE EQUATORIAL PLANE



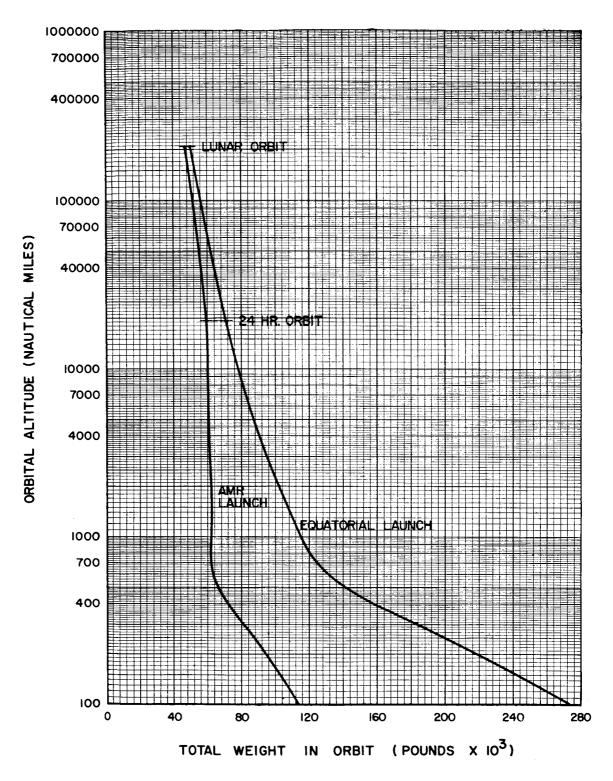
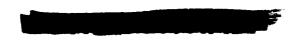


FIG. I-14: VARIATION OF THE TOTAL WEIGHT IN ORBIT WITH ALTITUDE RESULTING FROM AMR AND EQUATORIAL ORBITS FOR THE ADVANCED SATURN



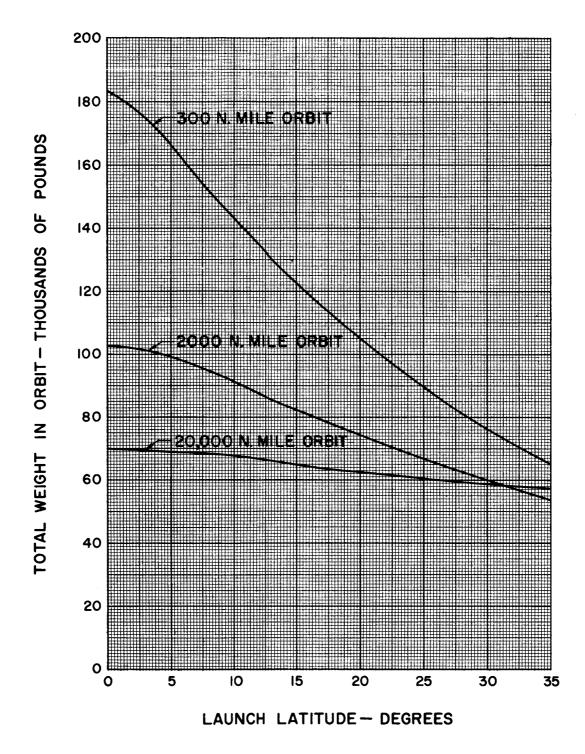
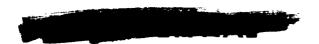


FIG. I-15: THE VARIATION OF TOTAL WEIGHT IN EQUATORIAL ORBITS WITH LAUNCH LATITUDE



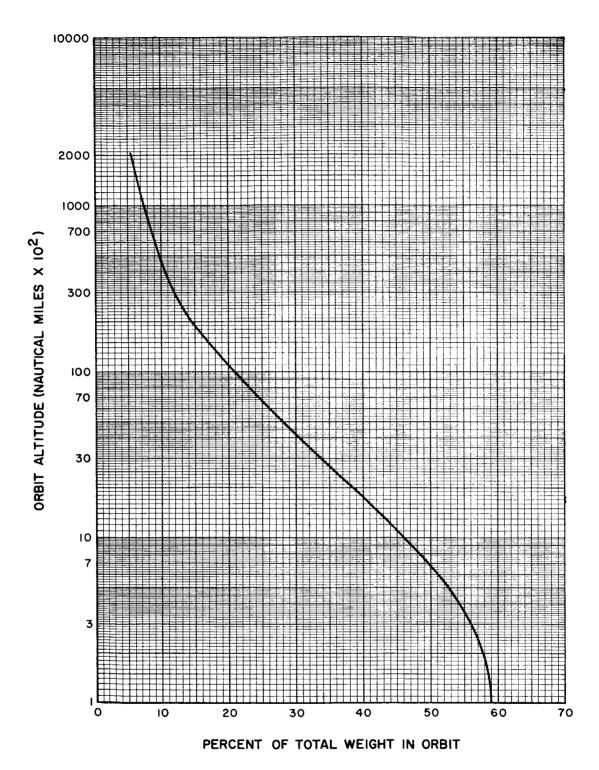
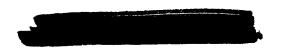


FIG. I-16: VARIATION OF THE PERCENT GAIN OF TOTAL WEIGHT IN ORBIT WITH ALTITUDE RESULTING FROM AN EQUATORIAL LAUNCH OF THE ADVANCED SATURN

TABLE 1-5: WEIGHT BREAKDOWN SUMMARY

WEIGHTS AND PERFORMANCE PARAMETERS FOR VARIOUS MISSIONS	SATURN BOOS	SATURN BOOSTER + ATLAS + CENTAUR I II III	+ CENTAUR III	SATURN BOOST	SATURN BOOSTER + TITAN I OR II + CENTAUR I II III III	I + CENTAUR III	SATURN BOOSTER + S-IV + 120K 0 ₂ /H ₂ + CENTAUR I II III IV	II	+ 120K 02	/H2 + CENTAUR IV
96 MINUTE ORBIT Life-Off Weight Cut-Off Weight Thrust Level Specific Impulse 3% FPR* Payload	1,050,150 400,150 1,498,850	321,150 78,150 360,000 312	63,800 37,800 30,000 420 2,150 30,850	1,073,400 323,400 1,498,850 258	244,400 74,400 200,000 310	63,800 37,800 30,000 420 2,150 30,850	1,180,350 530,350 1,498,850	451,350 201,350 450,000 420	175,650 97,650 120,000 420	88,100 62,100 40,000 420 3,350 53,800
24-Hr-Orbit Lift-Off Weight Cucoff Weight Thrust Level Specific Impulse 3% FPR* Payload	1,024,800 374,800 1,498,850 258	295,800 52,800 360,000 312	38,450 12,450 30,000 420 1,000 6,650	1,047,000 297,000 1,498,850 258	218,000 48,000 200,000 310	37,350 11,350 30,000 420 930 5,650	1,139,350 4 489,350 1 1,498,850 4	410,350 160,350 450,000 420	134,650 56,650 120,000 420	47,100 21,100 40,000 420 1,730 1,730
ESCAPE Lift-Off Weight Cutoff Weight Cutoff Weight Thrust Level Specific Impulst 3% FPR* Payload	1,027,450 377,450 1,498,850	298,450 55,450 360,000 312	41,100 15,100 30,000 420 1,150 9,150	1,050,100 300,100 1,498,850 258	221,100 51,100 200,000 310	40,450 14,450 30,000 420 1,100 8,600	1,143,350 493,350 1,498,850	414,350 164,350 450,000 420	138,650 60,650 120,000 420	51,100 25,100 40,000 420 1,930 18,400

* Flight Performance Reserve



The performance capabilities of the Atlas, Titan, and Saturn S-I vehicles were previously compared in Figure I-1. As would be expected, the SATURN vehicle is superior in performance. Figure I-17 shows the effect of launch site location on the payload capabilities of the SATURN S-I booster plus Titan II stages when launched from the AMR and the equator.

Figure I-18 shows the per cent gain in total payload weight resulting from the equatorial launch as compared to the AMR launch. A 70 per cent gain in payload for the 100 nautical mile equatorial orbit results from equatorial launches as compared to AMR launches. However, a gain of only 14 per cent exists for the 24-hour orbit and only 5.5 per cent for a lunar orbit.

The above data were computed from analytical formulas and have a numerical accuracy of about 1%. Certain second order effects were excluded, such as loss of liquid hydrogen during time spent in a parking orbit.

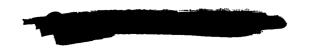
Studies by Space Technology Laboratories and ABMA (See Part IV) gave essentially the same results except that their values for total weight gained in the low altitude orbits were higher than the ones presented in this report. The translation of the velocity penalty into payload required careful consideration. If the vehicle can actually reach a circular equatorial orbit from the AMR, the equatorial launch can be handled precisely for small values of ΔV_T , by the assumption that the top stage propellant tanks are left partly unfilled with an equivalent weight added to the payload. The amount of propellant omitted, ΔW , can be calculated from the usual rocket equation:

$$\Delta W = W_o \bar{e} \left(\frac{\Delta V_T}{V_e} \right)$$

where W_0 is the total vehicle weight at final burnout for the equatorial launch and V_e is the final stage exhaust velocity: $V_e = I_{sp}$ (g₀) where I_{sp} is the final stage vacuum specific impulse and g₀ is the acceleration of gravity at the earth's surface.

It should be noted that 100 $\triangle W/W_O$ is the percentage penalty of total weight in orbit. The percentage penalty in <u>net</u> payload depends entirely on the structural factor or on the ratio of net useful payload weight to total weight.

If the majority of missions require low altitude equatorial parking orbits and large payloads, then launches from an equatorial facility into such an orbit is the most economical approach. Specific costs of the facilities at the two launch sites and the economical advantages of an equatorial facility are discussed in subsequent sections of this report.



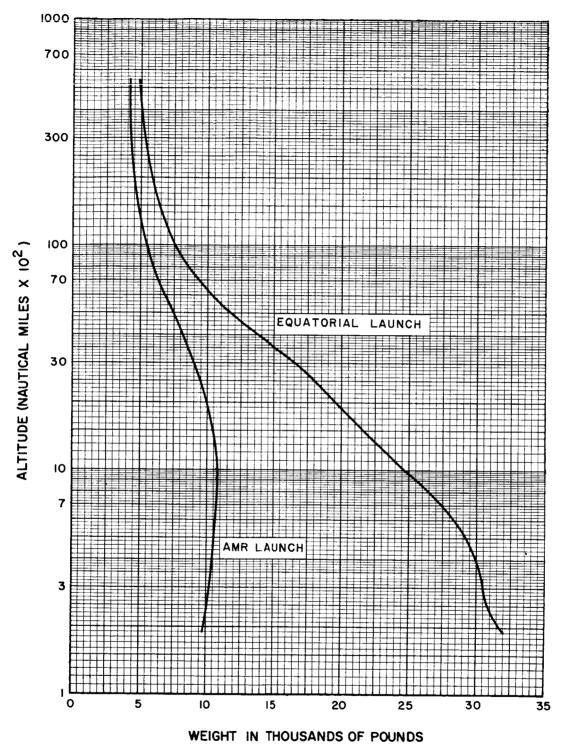


FIG. I-17: VARIATION OF PAYLOAD WEIGHT WITH ALTITUDE RESULTING FROM AMR AND EQUATORIAL LAUNCHES INTO EQUATORIAL ORBITS FOR THE SATURN S-I PLUS TITAN II



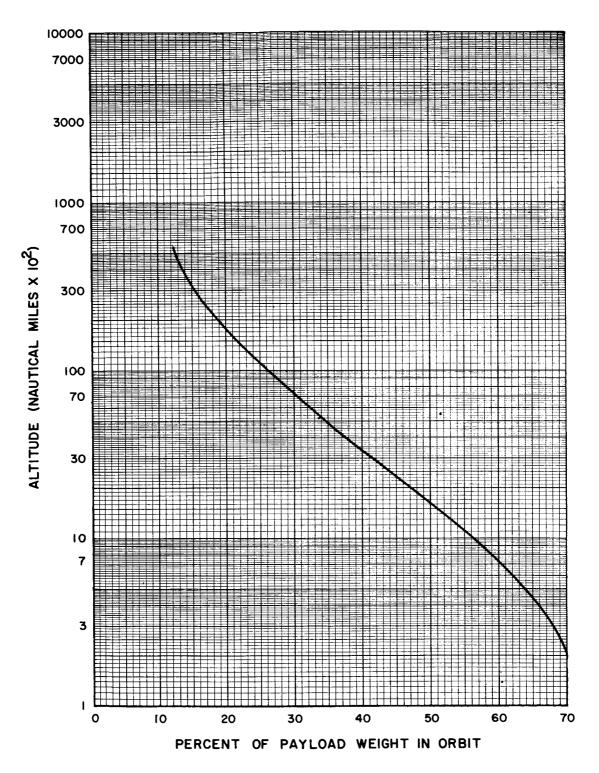


FIG. I-18: VARIATION OF THE PERCENT GAIN OF PAYLOAD WEIGHT IN ORBIT WITH ALTITUDE RESULTING FROM AN EQUATORIAL LAUNCH OF THE SATURN S-I PLUS TITAN II

F. GUIDANCE REQUIREMENTS

"The guidance and control requirements for the SATURN vehicle will require a considerable effort. Fortunately, adjustment of a limited number of components will satisfy most of the requirements." (ABMA Report DSP-TM-1-59)

Although detailed guidance and control requirements for various low-altitude satellite missions of the SATURN vehicle have yet to be specified, it is evident that they will be much more stringent than the requirements for early satellites.

It will be necessary to use inertial injection guidance, at least until the cutoff of the last stage. The additional weight of the injection guidance and control equipment in the last stage will be almost negligible for low-altitude orbits. In fact, some payload capability will be available for engineering tests in this area.

Later applications, however, will require an additionally fine orbital control system. This applies especially to rendezvous missions. Such missions require accurate timing and a fine terminal guidance to allow them to match the speed and course of their objectives within a reasonable period of time.

In summary, it will be necessary to provide the guidance and control equipment indicated in Table I-6 for low-altitude satellite missions. It is also seen that a logical sequence for the development of this equipment may be followed, beginning with injection guidance, altitude control, re-entry guidance, and orbital control, then progressing to the complete equipment required for guidance and control during rendezvous missions with re-entry.

1. Guidance Accuracy

Guidance accuracy can be affected three ways be a change of launch site location: (1) performance characteristics of inertial guidance equipment may be altered if it operates in an environment that is different from that for which it was designed; (2) relocation may alter the intrinsic geometry of the programmed guidance problem, whereupon such quantities as error coefficients may take new values—there is a certain degree of coupling between these two factors—and (3) if the launcher is mobile, there are, in addition, uncertainties about position orientation and states of motion, which, of course, are not present at fixed sites.

General Dynamics/Astronautics has made calculations of the errors involved in injection into a 100 n mile parking orbit from both land and sea launchers. Their results are summarized in the following table, which gives the errors in position and velocity at burnout:

TABLE I-6 GUIDANCE & CONTROL EQUIPMENT REQUIRED

FOR LOW-ALTITUDE SATELLITE MISSIONS

	Two	Tryng of Orbit		Fan inment	Equipment Required		
MISSION	Inclined	Equatorial	Injection Guidance	Altitude Control	Orbital Re Control	Rendezvous Timing	Timing
Engineering Tests							
Injection	×	×	×				
Altitude Control Systems	×	×	×	×			
Orbital Control Systems	*	×	×	×	×		
Re-Entry From Satellite Orbits	×	×	×	×	(x)		(<u>x</u>)
Scientific Exp. (Space-Medical)							
Without Re-Entry	×	×	×				
With Re-Entry	×	×	×	×			(×)
Orbital Operations							
Refueling		×	×	×	×	×	×
Space Station Construction		×	×	×	×	×	×



Table I-7

PARKING ORBIT INJECTION ERRORS

	Sea Launch	Land Launch
x, ft. (along trajectory)	1170	1010
y, ft. (out of plane)	1600	710
z, ft. (normal to x & y)	2240	1390
x, Feet per second	6.61	5.93
y, Feet per second	3.23	2.72
ż, Feet per second	7.46	5.94

"A study of the individual error sources as reported by General Dynamics/Astronautics showed that the main contributions come from the sensors themselves, i.e., the accelerometers and reference gyros. The data also showed that sea launch is not greatly inferior to land launch from the guidance point of view, particularly as the velocity along the orbit $\dot{\mathbf{x}}$ is by far the most important term, since it affects directly the period of the synchronous orbit to be established later.

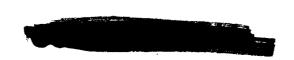
"The Martin Company has analyzed Titan II - Centaur guidance through injection into the synchronous equatorial orbit. Parking orbits were included in a comparison of attainable accuracies among AMR and equatorial island, drydock, and ship facilities. The one-sigma errors in the orbital elements of the final synchronous orbit are listed in the following table:

Table I-8
TITAN II CENTAUR - GUIDANCE ERRORS

LAUNCH SITE	AMR	ISLAND OR DRYDOCK	SHIP
Period, (SEC)	490	420	480
Semi-major axis, (FEET \times 10 ⁶)	1.6	1.3	1.5
Eccentricity	0.0080	0.0065	0.0074
Angular position, (M. RAD.)	0.97	1.0	1.6
Inclination, (M. RAD.)	2.1 '	2.1	2.1

"The apparent discrepancy of larger errors at the AMR than from the ship arises mainly from the translation of turning angular errors into errors in the magnitude of the fine velocity vector.

"The full implication of the difference shown in the preceding table can only be determined against specific system requirements. Generally, however, the variations are small. The non-periodic effects of the semi-major axis errors deserve the closest scrutiny. The maximum period difference of 70 seconds corresponds to approximately 1/3 degree per day differential longitude drift rate.





2. Flexibility of Launch Time

"For some missions, notably lunar missions, use of an equatorial launch site provides increased flexibility in the choices of launch times and in the size of the "firing window" during which launch can take place without degradation in performance or guidance accuracy."7

The following table shows the "firing window" for lunar missions from the AMR (28° N) South Point, Hawaii (18° N), and Christmas Island (2° N).

TABLE I-9: LAUNCH AZIMUTH VARIATION FOR A ONE-HOUR FIRING WINDOW

LAUNCH SITE	24° (MAX)	MOON DECLINATI
AMR	4.5°	6.0°
South Point, Hawaii	0.5°	3.5°
Christmas Island	0.3 ⁰	0.1°

G. OVERALL SAFETY CONSIDERATIONS

1. Safety Parameters

In the need for determination of whether present launch facilities could satisfy future space programs from a safety point of view, a study was performed by a joint Air Force - NASA Hazards Analysis Board with the following objectives:

a. Hazards Analysis

- (1) Define the hazards associated with the launching of assumed large space vehicles.
- (2) Analyze the degree of each hazard.
- (3) Develop preliminary design data upon which to base plans and decisions regarding the siting and safety considerations for space vehicle launch facilities, equipment, instrumentation and personnel.
- (4) Determine the precautions necessary to prevent undue hazards to the civilian population in adjacent uncontrolled areas.

b. <u>Blast Eff</u>ects

(1) To analyze blast effects to be anticipated from explosions of large vehicles and to establish the required clearance distance for controlled areas.

Fequatorial and Mobile Launch Operations and Facilities, Navy Department, 9 August 1961.

⁸ IBID



(2) To determine the blast effects on a biological target, including man.

c. Acoustic Effects

To determine maximum noise levels that civilian populations will find acceptable.

2. Safety Provisions (See Table I-10 and Figure I-19.)

The conclusions of the report are as follows:

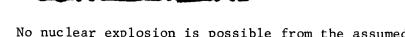
a. <u>Hazards</u>

- (1) Launching of large space vehicles, from shoreland at Cape Canaveral, is possible provided additional land is acquired on Merritt Island.
- (2) The hazards imposed by liquid and solid systems dictate separation distances from launch site to civilian population up to 35,000 feet.
- (3) Nuclear "upper stage" system dictates separation distances from the launch site to civilian population of at least 10 miles.
- (4) Operational hazards for liquid and solid boosters do not dictate going to off-shore launch sites. Future nuclear powered boosters may require off-shore or other remote launch sites.
- (5) Additional land acquired, which provides buffer zones to the uncontrolled civilian populace, is suitable for industrial and technical support use.
- (6) Public information programs to educate and condition the civilian populace and controlled area personnel to the operational hazards are needed immediately. The programs will alleviate fears and suspicions regarding the nature and magnitude of the hazards involved.
- (7) Additional studies to develop better data are necessary in all the hazards areas.
- (8) Meteorological conditions (such as wind velocity gradients, conversion layers and cloud characteristics) will have definite impact on the land area subjected to a given hazard.
- (9) People within the controlled area can be protected from launch hazards by evacuation, special conventional construction and/or blast resistant construction.



HAZARDS	Saturn C-1 1.5 x 10 ⁴ Thrust, Liquid System	Saturn C-3 3 x 10 ⁶ # Thrust Liquid System	10 x 106 # Thrust Liquid System	10 x 10 ⁶ # Thrust-Solid & Liquid Upper Stage System		12 x 10 ⁶ # Thrust Liquid System	12 x 10 ⁶ # Thrust-Solid & Liquid Upper Stage System	15 x 10 ⁶ # Thrust Liquid System	15 x 106# Thrust Solid & Liquid Upper Stage System	22 x 10 ⁶ # Thrust Liquid System	22 × 10 ⁶ ≢ Thrust Solid & Liquid Upper Stage System
Blast Over- Pressure	į			Class 2	Class 9						
1. 0.2 psi 2. 0.4 psi	10,100'	17,300'	21,300'	23,600'	30,400	23,100° 11,500°	22,600'	27,000'	24,900'	26,000' 10,550'	26,300' 13,200'
Acoustics 120db	8,000	12,000,	21,000'	21,000,1	21,000 ¹	23,0001	23,000'	25,000'	25,000' 14,000'	35,000'	35,000' 20,000'
Nuclear Radiation			1f 1,000,0 radius for	00 # Nuclea controllin	r Upper g area w	If 1,000,000 # Nuclear Upper Stage is used_radius for controlling area will be 52,800					
Fragments				-5,000' Maximum Radius-	fmum Rad	ius———i					
Fire				_750' Maxim	num Fireb	-750' Maximum Fireball Radius-					
Toxic			No Toxic p	ropellants	assumed	-No Toxic propellants assumed for these systems-	Sins				

From: SAFETY & DESIGN CONSIDERATIONS FOR STATIC TEST & LAUNCH OF LARGE SPACE VEHICLES



(10) No nuclear explosion is possible from the assumed nuclear rocket system.

b. Blast Effects - Conclusions

Acceptable levels of peak over-pressure were established as follows:

0.2 psi - Limit for uncontrolled area - No significant damage to personnel or facilities will occur.

0.4 psi - Limit for unprotected personnel.

0.75 psi - Interpad Separation Distance - Is based on assumed overpressure that vehicles will not withstand. (Note: If vehicles will not withstand 0.75 psi, blast deflectors will be required or pads must be resited. This will effect the radii shown on Cape map.)

0.75 psi - Limit for windowless ordinary construction.

2.0 psi - Limit for windowless, slightly reinforced construction.

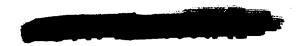
c. Blast Effects, Biological - Conclusions

Controlled areas on the basis of blast effects are relatively small in comparison with acoustic and nuclear hazard consideration. Maximum distance from explosion center 3,900 feet.

d. Acoustic Effects - Conclusions

Based on a launching schedule of 2-4 launches/month of 22.0×10^6 lbs. thrust clustered vehicle or vehicle of this size, the estimated power level (acoustic power output) is estimated between 0.5×10^9 watts. The frequency of this power is related to the Strouhal number of the gas flow, giving a frequency distribution from two cycles/sec. to at least 10,000 cycles/sec. Maximum energy is in the subaudible range 2-20 cycles/sec.

During launch, the total time duration of the significant peak region is not expected to exceed two minutes for any vehicle with an acceleration of 8 $\rm ft/sec^2$ or greater.



e. Overall Conclusion

The overall conclusion, reached through the acoustic level study, based on the uncertainty of building criteria and of the inexperience with the effect of subaudible noise on human reaction, is that the OASPL limiting level of 115 db for this type spectrum appears to be the maximum level of exposure for populated areas. Therefore, minimum distance from launch site to residential areas should be not less than 4 miles (120 db figure). To provide a margin of safety, this distance should be increased to seven miles.

H. PRINCIPAL PERFORMANCE BENEFITS

The principal performance benefits derived from an equatorial launch site are as follows:

- 1. The payload capability for launching into equatorial orbits is greater from an equatorial site than from non-equatorial sites, particularly for low altitude orbits. As previously shown, an increase in payload as high as 70 per cent can be obtained by launching from the equator rather than from the AMR for a 100 nautical mile altitude orbit. This payload advantage decreases rapidly as the altitude is increased until only a 14 per cent gain in payload can be obtained for the synchronous 24-hour orbit.
- 2. Opportunities to launch directly into rendezvous orbits occur on every pass of a satellite in an equatorial orbit. For non-equatorial rendezvous, occasions for direct launch without the "dog-leg" maneuver occur only once every 100 orbits. This implies of course that a low equatorial orbit would be ideal for a space station since shuttle trips carrying supplies and personnel could be made with a minimum of delay.
- 3. An equatorial launch site is the only one that can provide the capability to launch directly into the plane of other orbits at any inclination angle, at the proper time of day, without "dog-legging" with its attendant performance penalties and added guidance complications.
- 4. Range safety problems associated with land overfly, stage impacts, and contamination by nuclear propulsion systems can be minimized greatly by a carefully selected equatorial launch site.



FIG. I-19: VARIATION OF NOISE ATTENUATION WITH DISTANCE

NOISE LEVEL (db)

II. FACILITIES AND GENERAL COSTS

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A. GENERAL

Cost estimations for space programs vary according to (1) the amount of research and development required to produce the desired vehicle, (2) the cost of production, (3) the cost of building adequate launch facilities, (4) the particular site and its remoteness from raw materials, skilled personnel, etc., and (5) the frequency of launch. The following facilities and estimations for constructing an equatorial launch site are based on descriptions and figures obtained from library reports on Saturn and Atlas series programs. These figures were then adjusted so that the number of launches per year were the same, and so that the period of construction and operation was eight to nine years.

An overall cost factor of 3% per year should be used to compensate for normal inflation costs. For overseas operation, personnel salary costs were increased by 1.4, technical facilities were increased by 1.57, and island support facilities were increased by 1.5. All cost figures are in millions of dollars, and do not include tracking sites. Operation and maintenance figures for Atlantic Missile Range were not available, and estimates for cost factors were made from previous efforts on Kwajalein Island.

B. PROGRAMS

The following programs present a sample of current planning as to number of pads, complexes, sophistication of checkout (manual, semi-automatic, or automatic), community facilities, storage, and maintenance facilities. Large differences in cost are due to differing concepts of terminologies and item inclusiveness, making comparison impossible: originating cost investigators do not disclose exactly what is included in a general category (such as Communications), so that reports may differ by as much as one hundred million dollars.

One Saturn and one Atlas-Centaur program are presented and referenced to the original report.

Saturn - Project Horizon

1.

- a. Facilities. The following descriptions are of a complex similar to AMR type 37. Proposed location Christmas Island.
 - (1) Launch Complex Area (see figure II-1.)

"The equatorial site consists of four launch complexes for a total of eight launch pads, eight vertical structures, and four blockhouses. The eight launch pads are arranged in a line roughly north to south.

"The launch pads are large concrete slabs which are spaced some 3155 feet apart. At the center of each pad is the launch pedestal which will hold the missile securely during servicing and will deflect the rocket exhaust gases as required during firing.

"Mounted on the launch pad and adjoining the launch pedestal is the umbilical tower, a steel mast with adjustable arms for connections to the vehicle stages before launch. The blockhouse is located 2,700 feet from both launch pads. It is a reinforced concrete building in which the launch countdown is conducted. The blockhouse is connected to the launcher and umbilical mast through cableways providing electrical, pneumatic, hydraulic, and communications services.

"The propellant storage and transfer facilities are located between the pads

"The vertical launch structure, rolling on rails, is thought of as being a structural steel checkout facility serving each launch pad. Its structure includes adjustable platforms which inclose the vehicle during checkout, and if used for assembly, provides two cranes for hoisting the vehicle units. If other means of hoisting for assembly are available, the vertical launch structure does not need large cranes."

The following buildings and equipments are included in the Launch Complex Area:

Blockhouse Cableway and Amplifier rooms 2 Pads

Staging Building LOX Facility (20,000 gal) 2 Service Structures

^{1&}lt;u>Technical Considerations and Plans</u> (Classified), Project Horizon, Volume I, Department of the Army, 9 June 1957, pp. 214 - 219.

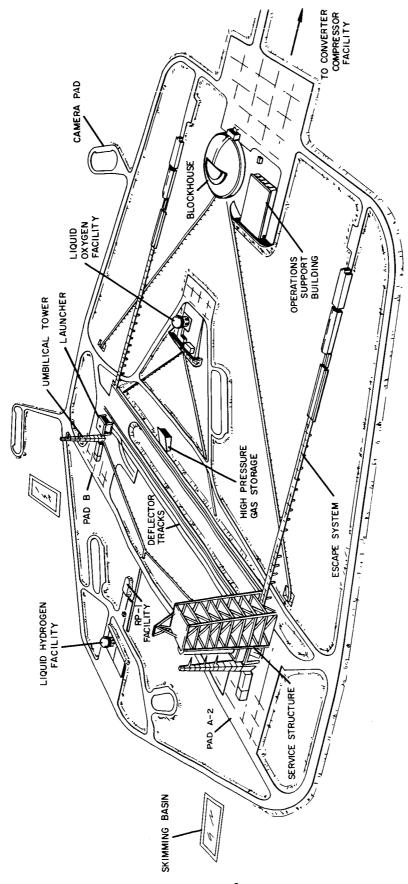


FIG. II-1: SATURN LAUNCH COMPLEX 37

Fuel Facility (60,000 gal) High pressure Gas Facility Instrumentation Sites LH₂ Facility (50,000 gal) Roads and Utilities Operations Building (75,000 sq ft)

(2) Launch Support Area (see figure II-2.)

A total of 200,000 sq ft is required for assembly and checkout buildings, including eight units as follows: 18,750 sq ft assembly and checkout area, with 35 ft clear height and a 60 ton bridge crane; 6,250 sq ft for shops, laboratories, storage, and offices. The entire area should be designed to maintain 40% RH at 80° F.

A total of 100,000 sq ft is required for payload checkout buildings, including four units as follows: 25,000 sq ft area with 35 ft clear height and a 40 ton crane. Checkout and assembly requirements include facilities for decontamination and sterilization. Area should maintain 40% RH at 80°F.

A total of 260,000 sq ft is required for vehicle storage, including 26 units of 10,000 sq ft each. No crane is required if vehicles are stored on transporters.

An anticipated requirement for payload storage is 23,000 sq ft.

A total of 50,000 sq ft is required for technical shops and test facilities, including a 36,000 sq ft shop area with a 60 ton bridge crane, and a 9,000 sq ft tool and storage area. On-site maintenance and repairs of pads and towers is assumed.

A total of 30,000 sq ft is provided for medical laboratories and holding facility to meet research and laboratory needs. The holding facility will be adjacent to the hospital for isolation and control of intransit personnel: this facility will provide secluded living quarters, dining, and recreation facilities for 30 persons.

(3) Service and Logistic Facilities

"Approximately seven miles of heavy duty roadway, 28 feet in width, will be provided between the cargo pier, the vehicle assembly and storage area, and the launch complexes. This roadway and the

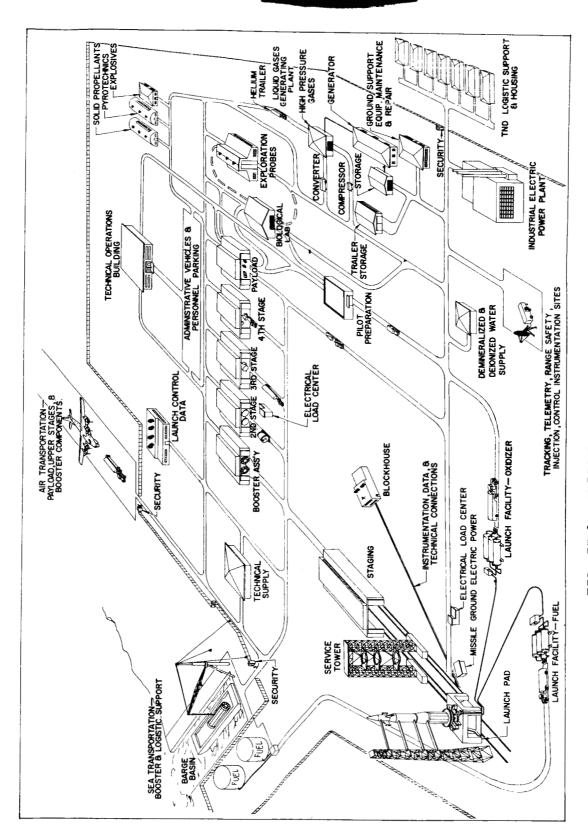


FIG. II-2: TYPICAL SATURN LAUNCH COMPLEX

approximately 220,000 sq yds of apron areas adjacent to the various buildings will be designed for the

to the various buildings will be designed for the 100 ton load of the vehicle transporter. In addition, approximately 58 miles of primary and secondary roads will be required exclusive of streets in the built-up housing and community areas.

"Primary sewage treatment is considered adequate for a site such as Christmas Island. Plant capacity of 1.2 million gal per day will be required.

"An estimated 50,000 pounds of waste per day will require a waste incinerator of 8,000 pounds per hour capacity.

"A water supply of 2.0 million gal per day will be developed from streams, wells and/or from fresh water lagoons as applicable. Facilities provided include treatment plant and pumping stations. Approximately 1 million gal elevated storage and two 12,000 gpm pumping stations with reservoir for fire and flushing requirements in the launch area.

"The estimated electric power requirement for the site is 56,000 kw. A steam plant with four 20,000 kw units (one standby), together with a primary distribution system totaling approximately 35 miles, is required.

"Total bulk storage for bulk fuel will be 8 million gal, based on the following requirements: power fuel, 1.5 million gal per month; technical fuel, 1.5 million gal per month; jet fuel and AVGS, 1.0 million gal per month; and gasoline and miscellaneous fuel, 0.5 million gal per month.

"Since there will be requirements for considerable quantities of LOX and LH₂ at the equatorial launch site, facilities will be provided for their generation. These facilities will have the capability of generating and pumping from the plant to launch complex storage facilities.

"Estimated port facilities requirements for handling the necessary incoming supplies and equipment, and booster recovery operations, include the following: Channel, 200 ft wide, 35 ft deep, 11 miles long; dry cargo pier, 90 by 500 ft, with two 100 ton cranes; POL wharf 40 by 300 ft, and pumping

station; LSD berthing facilities; small boat docks; transit warehouse; port administration; and cafeteria facilities.

"Site work and miscellaneous utility items include clearing, grading, etc., construction of streets, curbs, walks, lighting, secondary electrical distribution, sewage collection, storm drainage, fencing and bulk fuel distribution to the launch areas.

"Service facilities include general administration and headquarters building, fire station, security facilities, general warehousing, maintenance shops, bakeries, laundry, dry cleaning plant, ice plant, refrigerated warehouse and meat cutting, mechanical and electrical repair shop, salvage and surplus property facilities, signal office and shop, telephone exchange, communication center, radio transmitter and receiver station, photo laboratory and film library, motor repair shops, gasoline station and supporting facilities, exchange maintenance shop, exchange retail warehouse, motor pool, and transportation office.

"The temporary construction camp will provide temporary accommodations for 2,500 persons and will include housing, dining, administration, recreation, stores, dispensary, bakery, cold storage, general warehousing, laundry, material sheds, temporary power, etc.

"The airfield facilities include a 200 by 11,400 ft runway, four helicopter pads, hardstands, taxiways, lighting, navigational aids, compass base, hangars, fire and rescue station, operations building and control tower, passenger and freight terminal building, parts storage and flammable storage.

(4) Housing and Community Facilities

"These facilities were based on a total installation population of 10,000 including 4,600 dependents.

"Housing includes 2,000 family units, 3,500 bachelor type quarters, and 100 spaces for transit personnel.

"Medical facilities include a 100-bed hospital on a 200-bed chassis and a 14-chair dental clinic.

"Community facilities include department store, cafeteria, gasoline service station, bowling alleys, bank, grocery store, chapels with religious education facilities, craft shops, entertainment work shops, gymnasium, library, club facilities, swimming pools, bath houses, post office, theater, dependent schools, and miscellaneous outdoor recreation facilities.

"Support for bachelor quarters includes dining, supply, administration and motor part facilities, stores, and gymnasium." $\!\!\!^{2}$

Ъ.	Costs		(in mill	ions of	dollars)
	(1) Const	truction			426.0
	` '	Housing and Community Faci Launch-Control Facilities Normal Inflation Unforeseen Costs	lities	136.3 103.6 82.7 37.0 35.5 30.9 426.0	
	(2) Opera	ation and Maintenance (six	years)		605.0
	(3) Grou	nd Support Equipment			107.8
	(4) Tran	sportation			83.4
	(c)	Airlift Support Construction Materials Vehicle and Payload Contai	ner	31.4 24.6 11.9 8.8 5.6 83.4	
	(5) Payl	oad Packaging			86.9
	(6) Comm	unications Systems			212.1
	(7) Rese	arch and Development			239.2
	(8) Trai	ning of Launch and Checkout	Crews TOTAL	1	25.0 ,785.4

²<u>Ibid.</u>, pp. 216-219.



2. Atlas-Centaur

- a. <u>Facilities</u>. The following descriptions are of a complex similar to AMR type 36 at Canton Island (see figure II-4).
 - (1) Launch Complex Area

"The launch complex is a permanent launch facility similar to those of AMR and PMR. The dry launch pad and support structure is of steel-reinforced concrete construction on land requiring no special foundation preparation. The rail-mounted mobile gantry service tower and umbilical tower are modified versions of similar existing steel construction at AMR and PMR. Service facilities, including the propellant storage and pressurizing system with blast wall separation, use mobile facilities where such exist.

"Launch control is provided from a launch control building or blockhouse of steel-reinforced concrete. The design of the building is based on requirements established for existing land installations. The building provides the environmental conditions necessary to protect the launch control equipment and personnel."

The following buildings and equipments are included in the Launch Complex Area:

Launch Operations Building Propellant Storage with GSE

Blockhouse Propellant Loading

System

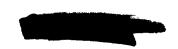
Launch Pad TV Pads

Gantry Cable Tunnel

Missile Service Tower Utilities, Fire Protection

Umbilical Tower Roads, Fencing Telephones, etc.

³Equatorial and Mobile Launch Operations and Facilities (Classified), Navy Department, 9 August 1961, pp. C-7 - C-10.



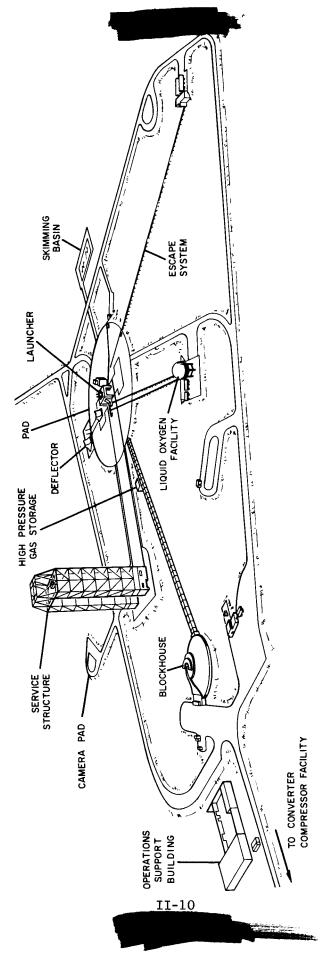


FIG. II-3: SATURN LAUNCH COMPLEX 34

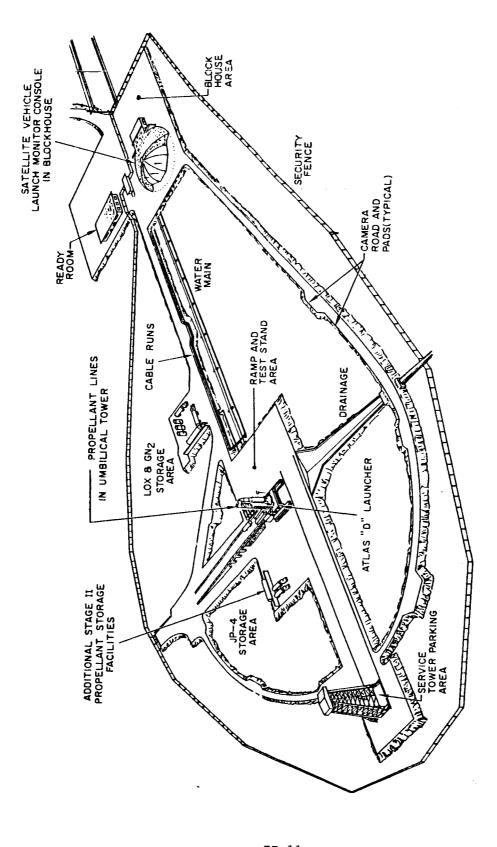


FIG. II-4: TYPICAL ATLAS LAUNCH COMPLEX

(2) Launch Support Area

"The Launch Support Area houses the structures required in direct support of the launch site and is located immediately beyond the ground safety limit lines. It includes a vehicle assembly building, an operations control building, and various fixed installations and mobile vans with range instrumentation and other requirements.

"The vehicle assembly building will be an economy hangar utilizing a 60 - 40 low-high bay ratio. The allowance for a combined facility housing 1st and 2nd stage boosters, payloads, shops, labs, and environmental areas is 30,000 square feet. The structure is of high bay steel frame and concrete masonry units.

"The operations control building has precast coral concrete roof framing, deck, and roof. It houses instrumentation for range safety and control, range timing, data processing, and administrative communication.

"The tracking radar, telemetry vans, range surveillance equipment, meteorological, and optical facilities are in the Launch Support Area. The buildings necessary to house these units are of the same type of construction as the range operations building and have environmental control. They are interconnected as required by land lines. Communication control and data transmission communications equipment are also located in the technical support area in two buildings, a transmitter and a receiver building, of the same construction. These buildings are radio interference isolated from each other and from other instrumentation equipment."

The following buildings and facilities are located in the Launch Support Area:

Tracking Equipment

Range Surveillance

Building

Telemetry Equipment

Electronic Sky Screen

Surveillance

Optical Tracking Facility

⁴Ibid., pp. C-8 - C-10.

Meteorology

FIC/EMS Building

Communications

Communications Facility

Photographic Laboratory

Telemetry Facility

- -

and Antennas

Atlas Missile Support Building

Photo Laboratory

Meteorology Facility

Administration and Engineering Building

Cable Plant

Utilities, Fire

System

Electrical

General Base Shops

Missile Fuel Facilities

Roads

Police Facility

Fire Station

(3) Administration and Housing

"The administrative and community housing facilities... include personnel quarters, hospital, messing, and recreation facilities. The buildings are of concrete masonry with precast coral concrete roof, framing, and deck, and either precast coral concrete or wood plank roofing. All buildings housing personnel are air conditioned."5

These facilities include:

Administration Building

Provost Office

Structural Fire Station

Dispensary

Cafeteria

Housing, EM Type

Barracks

BOQ with Mess

Subsistence Building

Guest and CPO Type Barracks

Welfare Facilities

Bank and Post Office

Chapel

⁵Ibid., p. C-9.

Barber, Tailor Shops, etc.

Bakery and Store

Warehouse

Recreational Facilities

Roads and Streets

Utilities

Salt Water Fire Protection

Electrical Substation

Sewage System

Telephone, Fire Alarm, etc.

Lighting System

(4) Harbor Area

"The harbor area ... includes dock facilities, base support, supply, general and propellant storage, power, water, and sanitary treatment and disposition. Buildings in this area are of the same type of construction as the technical support and administrative areas. Because of climatic conditions, the use of exposed structural steel is avoided, and aluminum or wood is used wherever possible."6

Harbor facilities include:

Shed Transit	Toilet Facilities
Dredging	Paving
Public Works	Motor Pool, Incin- erator
Storage Facilities	Cold Storage
Flammable Storehouse	Open Storage

Waterfront Administration Crane - 25 ton capacity

Utilities, Phones, Fire Alarm

Technical Equipment Stores

Saltwater Fire Protection

tribution

Electrical Dis-

^{6&}lt;sub>Ibid., p. C-8</sub>

(5) Airfield Area

"The tower must handle increased traffic. Adequate runways for jet aircraft must exist." 7

The airfield facility includes:

			Tower	Runway	
			Electrical Substation	Electrica bution	l Distri-
			Telephone Systems	Fire Alar	ms etc.
b.	<u>Capi</u>	tal C	osts	(in millions	of dollars)
	(1)	Laun	ch Complex		24.10
	(2)	Inst	rumentation and Controls		12.00
	(3)	Supp	ort		36.10
		(b) (c)	Facilities Administration Housing Harbor Facilities Airfield Modifications	16.8 11.4 6.2 1.7	
			TOTALS		72.20
c.	Annu	a1 Op	eration and Maintenance Cost		
	(1)	Laune	ch Operations		11.00
		(b)	Salaries Contractor Refurbishing Launch Facilities	8.5 0.5 1.0	
	(2)	Base	Support		7.60
			Salaries Propellants Facilities Base Operations and Maintenance	5.0 0.2 2.4	
	(3)	Trans	sportation		1.90
		(a) (b)	Personnel Air Support	0.3 1.6	
			TOTAL for eight year	rs	240.20

^{7&}lt;sub>Ibid., pp. C-9</sub>.

d. Adjusted Costs for a launch rate of 48 per year, with six complexes. These figures do not reflect research and development for vehicle and payload costs, but are based upon a fully developed vehicle requiring standard launch support such as AMR Type 36. Estimated lead time for construction and operation is 48 months. Estimated number of personnel required is 3,500 engineers, scientists, technicians, and support personnel.

(1)	Capital Costs		(in millions of dollars)
	(a) Launch Complexes	•	144.6

(a)	Launch Complexes	144.6
(b)	Instrumentation and Controls	72.0
(c)	Support	212.9

(2) Operation and Maintenance Cost (6 years)

(a)	Launch Operations		396.0
(b)	Base Support		453.06
(c)	Transportation		68.4
(d)	Propellants		18.0
` ,	-	TOTAL	1,365.5

3. Other Programs

In addition to the programs just discussed, of which full descriptions of technical, support, and logistics facilities were available, useful cost information has been obtained from sources which do not describe such facilities.

The proposed NASA Complex 39, for example, gives figures for six AMR type 37 complexes (48 launches per year), research and development, construction, and equipment only. No facilities, either logistic or support, are described. Applying the cost factors 1.57 or 1.5 to compensate for remote location, the following figures result: (in millions of dollars)

		US	Equator
(1)	Blockhouse and pads	80.00	126.00
(2)	Service Structures	42.60	66.80
(3)	Range Utilities	18.10	28.40
(4)	High-pressure Gas	11.40	17.90
(5)	Documentation, Studies, Models	0.33	0.33
(6)	Instrumentation Site	26.40	41.50
(7)	Umbilical Tower	11.40	17.90
(8)	Booster Anchorage	1.80	2.83
(9)	Propellants	64.92	101.80
(10)	Launch Support Equipment	3.54	5.25

(11)	Operation Support Building	5.40	8.49
(12)	Firing Accessories	35.50	52.50
(13)	Erection, Handling, Servicing	3.60	5.62
(14)	Launcher and Arms	25.80	40.60
(15)	Deflector	5.34	8.40
(16)	Electrical GSE	3.60	5.62
(17)	Documentation, Studies, Models (GSE)	0.80	0.80
(18)	Checkout and Launch Consoles	12.00	18.80
(19)	Land Fill	_18.00	
	TOTALS	370.43	549.67

Figures II-5, II-6, and II-7 are included to illustrate the wide degree of variation in the originating reports.

C. TRACKING FACILITIES

Downrange tracking facilities are required in support of launch sites in order to provide the following functions:

- (1) Range safety.
- (2) Receive, relay & store data transmitted by space vehicle.
- (3) Provide secondary control of space vehicle.

The number, size and complexity of the stations are dependent upon the requirements for specific launch programs. Present and future space programs will require more equipment and personnel at the tracking stations (ex. project Mercury).

The cost of land acquisition and the construction of facilities required to house equipment and personnel has not been considered in this report, primarily due to the generalized location of these sites and the cost variation that could be expected. The cost of a downrange site is expected to range from three to twelve million dollars, based upon cost values for the following equipment:

a.	Guidance System	5.40
b.	Radar - FPS/16	1.50
c.	Radar - AN/MPS-25	2.80
ď.	Communication Vans	0.01
e.	Command - Destruct AN/FRW-2	1.20
f.	Transmitters - HF55B	0.03
g.	Receivers - HF55B	0.06
h.	Transceivers, UHF - AN/GRC-27	0.08
i.	TV Camera - Display Units	0.10

ITEM	120 LAUNCH/YEAR	48 LAUNCH/YEAR	12 LAUNCH/YEAR
Launch and Technical Support (1)	98°987	309.39	152.87
Administrative Support (2)			
Community Facilities			
Transportation and Utilities (3)	208.45	104.00	39.99
TOTAL	695.31	413.39	192.86

Includes range overhead, propellants, prelaunch checkout and launch operations. Included in range overhead.

Transportation: AMR to West Coast by LSD, approximately 4300 statute miles. Cost factor of 1.5 for overseas location. NOTE: 3(3)

Costs are in millions of dollars.

COMPARATIVE COSTS FOR DIFFERING LAUNCH RATES FIG, II-5:

	CATEGORY	АВМА	PARSON'S a	AEROJET
1.	Launch & Technical Support	156	55.2 b	114.5 e
2	Admin. Support	14.4	13.2	25.0
ကိ	Community Facilities	41.8	30.8	49.7 c,d,f
4.	Transportation & Utility	49.2	46.4	
	TOTAL	261.4	145.6	189.2

Fourth increment construction - intermediate permanent facilities. . ф. с. ф.

Stateside costs, factor of 2 used for comparison

First two years increment

Instrumentation Range Safety (c) Technical Support Aerojet categories: (a) Launch Facilities (b) (d) Communications (e)

Aerojet Category - Operational Facilities ÷.

Aerojet Category - General Support Facilities

Saturn G-2 Operational Modes Study - Martin Go. Ref;

COST ESTIMATES OF AN EQUATORIAL LAUNCH FACILITY FIG. II-6:

	PROGRAM COST ^a		LAUNCH	ED AT
	•		AMR	EQUATOR
1.	Saturn Booster + Atlas + Cer	ntaur	(1288) ^b	(1453)
2.	Saturn Booster + Titan (120	in.) + Centaur	(1229)	(1394)
3.	Saturn Booster + Titan (160	in.) + Centaur	(1254)	(1419)
	ITEM COST			
1.	Saturn Booster	825		
2.	Guidance	50	,	
3.	Atlas + Centaur	(317)		
4.	Titan (120 in.) + Centaur	(258)		
5.	Titan (160 in.) + Centaur	(283)		
6.	Equatorial Launch Facility	261		
7.	AMR Launch Facility	96		

 $^{^{\}mathrm{a}}\mathrm{Cost}$ estimates based on 100 launches during first 4 years of operation.

Ref: Saturn System Study (Classified), ABMA, 13 March 1959.

FIG. II - 7: COST COMPARISON, AMR vs EQUATORIAL SITE

 $^{^{\}rm b}$ Figures in parentheses indicate 20% added to conservative contractor estimates.

j.	TV Cables - Boxes	0.05
k.	Antenna, Transmitting	0.02
1.	Antenna, Receiving	0.01
	Total Per Site	$\overline{11.76}$

D. TRANSPORTATION COSTS

Transportation costs depend upon the launch rate and the requirement for high speed movement. The approximate time for transportation from the west coast to an equatorial site is from ten to fifteen days, assuming vessel speeds of eighteen knots. The approximate daily cost of operating a vessel is between \$2,500 and \$3,000; a round trip would therefore cost approximately \$75,000. For a launch rate of 48 per year, six transports would be required to make nine trips per year.

A breakdown of the yearly cost of operating a vessel of the C-2, C-3, and C-4 series is as follows:

a.	Fuel and utilities	\$147,000
b.	Supply and equipment	116,000
c.	Restricted availabilities	39,000
d.	Overhaul	189,000
e.	Personne1	211,000
f.	Insurance	51,000
	TOTAL (Based on 55% utilization)	\$753,000

Reports covered by this study show that an LSD (Landing Ship Dock) could be converted to serve as a carrier for the Saturn class vehicles. Estimated operating cost increase would be \$500 to \$1,000 per day.

Overall transportation costs are reflected in total program costs: these figures include the initial cost of moving supplies, equipment, and personnel to a remote launching site.

E. REMOTE VS STATESIDE CONSTRUCTION COSTS

- 1. <u>Direct Costs</u> in remote areas are due to a lack of local skilled labor, raw materials, and remoteness from populated areas.
 - a. The labor problem is solved by the movement of skilled personnel to the construction area. More pay, longer vacations, and rotation to the US are incentives offered to competent skilled tradesmen as an offset for the lack of benefits that are normally present. Through actual use of these practices, the government has found that an additional cost factor of 1.4 will provide close estimations for planning purposes.

- b. The lack of raw materials at a remote site requires an initial mass movement of supplies from US ports. The government has found, through actual experience in the Pacific, that the cost of technical facilities requires a cost factor of 1.57, and the cost of technical support facilities is an additional 1.5.
- c. Remoteness from populated areas requires additional planning and expense: community facilities, housing, recreation areas, and community support facilities in stateside locales are normally privately owned or are part of municipal property. In the case of a remote launch site, the government must assume the additional cost of supplying living quarters, recreation areas, and supplies for the civilian contractor personnel, government dependents, and technical and support personnel at the site.
- 2. <u>Indirect Costs</u> are the distance from the operating agency's headquarters, the construction period and its unforeseeable delays, and the effect of national and international politics.

Unless the launch site is large, the need for coordination between higher echelon personnel will at times cause delays in decisions affecting the launch program. Delays in the scheduled construction period, both natural and man-made, mean that schedules must be altered, and additional funds be provided to meet deadlines. Problems on a national and international level will affect the cost of a remote launch site: if the site is not owned by the U.S., negotiations must be made for purchase or rental rights. Problems arising in the U.S. due to transfer or launch operations from a stateside launch area and the effect of the transfer on the economy of that area will present additional arguments to be considered in the construction of a remote launch site.

F. EQUATORIAL VS NON-EQUATORIAL LAUNCH COSTS

The cost of launching from a non-equatorial launch site is directly related to requirements for more vehicles, larger boosters, or a reduction in payload. The additional development cost of a new higher thrust booster is justified only when it is shown that future space programs would require larger systems, and that additional costs would not exceed the cost of constructing and operating an equatorial site. In addition, absolute payload requirements for any specific launch program must be met, else a successful launch would require the development of a new booster or the transfer of operations to an equatorial site.

It can readily be observed, from our current and future space programs, that many proposed programs would benefit from

an equatorial launch. Notable among these are the twenty-four hour synchronous satellite, rendezvous missions for outer space and lunar probes, low altitude equatorial orbits, and manned space stations.

Some of the factors affecting non-equatorial launches which must be considered are (1) the complexities of guidance control requirements for rendezvous and manned space programs, (2) and inherent increased reliability, due to difficulties associated with rendezvous missions, which must be built into systems used for manned space programs, and (3) the additional need for backup vehicles on the pad in case of malfunctions occurring during launch countdown on the primary vehicle.

The economic analysis of an equatorial launch site must be based on specific program requirements in order to determine the least costly mode of operation. The range of costs relating to launch site requirements does not permit evaluation of economic factors, since (1) the number and type of launch complexes, (2) the permanence of new facilities, (3) the sophistication of launch complexes, (4) the launch rate, and (5) logistics all affect the overall program cost.

The cost, according to STL's <u>Equatorial Launch Site Study</u>, March 1960, of using a non-equatorial site is the payload penalty in dollars figured at the appropriate unit cost of a pound in orbit.

The following equations were developed by STL and plotted (see figure II-8) for a 300-nautical-mile circular equatorial orbit:

$$c_{e1} = w\omega + c_{f}; c_{ne1} = \left(\frac{w}{P}\right)\omega + c_{f}$$

$$\triangle \mathbf{C} = \left(\frac{1}{P} - 1\right) \mathbf{W} \omega$$

The plot shown in figure II-8 is for P=0.35, corresponding to the most advantageous structural factor (no useless structure in orbit). It should be noted that the ratio P increases for high altitude orbits. At approximately 73,000 nautical miles, P=0.82.

The crossover is also developed in <u>Equatorial and Mobile Launch Operations and Facilities</u>, US Navy. This report pointed out that STL's analysis was made on the basis of a launch site cost of 200 million dollars, assuming a <u>total</u> payload in orbit, or including

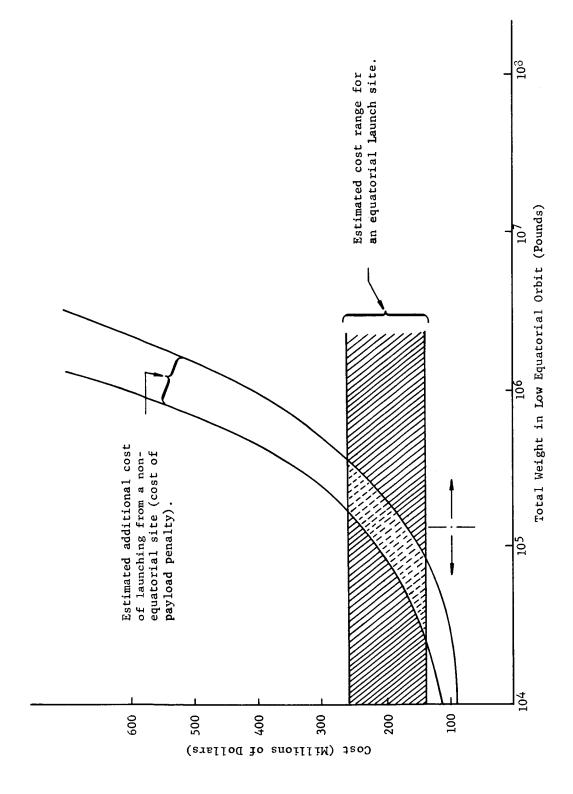


FIG. II-8: COST VS TOTAL WEIGHT IN LOW EQUATORIAL ORBIT

a booster stage. The Navy Department made its comparison on a launch site cost ranging from 46 to 161 million dollars, and on the basis of total <u>useful</u> payload in orbit. Their calculations were for a Titan II-Centaur configuration, and show crossovers ranging from 26.1 to 93 thousand pounds in orbit, with range variations due to varied launch facilities costs.

In order to determine the economic crossover point of an equatorial launch site and the space programs associated with it, the type of mission, type of booster and its reserve capability, the number of launches, and the cost of developing the launch site in terms of program delay must be considered.

The S.T. L. cost analysis was made under the most advantageous conditions; that is, a low equatorial orbit, where payload capabilities are quite different. In order to determine accurately the crossover point at which an equatorial site is more economical, the cost of completing a specific type launch with a given vehicle must be determined. For \underline{n} programs, then \underline{n} advantages must be summed and compared with the additional cost of constructing and operating an equatorial site and the overall cost of completing the program. (See figure II-9.)

Another general equation shows that an equatorial site will pay for itself on a total weight in orbit basis.

Let W = total weight required for orbit $w_e = \text{payload/lbs}, \text{ equator}$ $w_n = \text{payload/lbs}, \text{ non-equatorial site}$ C = total general cost $C_v = \text{vehicle cost } (\$6.5 \times 10^6)$ $C_e = \text{fixed cost}, \text{ equator}$ $C_n = \text{fixed costs}, \text{ non-equatorial site } (500 \times 10^6)$ $C_{te} = \text{total costs}, \text{ equator}$ $C_{tn} = \text{total costs}, \text{ non-equatorial site}$ $a = \text{ratio } \frac{C_e}{C_n}, \text{ where } a > 1$ $\triangle C = (C_{te} - C_{tn}) = (C_e - C_n) \neq WC_v (\frac{1}{We} - \frac{1}{Wn})$

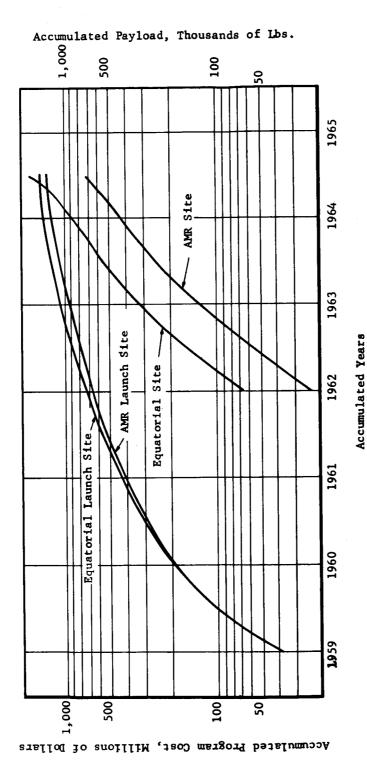
then

$$\triangle C = C_n (a - 1) \neq WC_v (\frac{1}{we} - \frac{1}{wn})$$

for C_n (a - 1)>WC_v ($\frac{1}{w_e}$ - $\frac{1}{w_n}$) non-equatorial launch is more economical

for C_n (a - 1) \leq W C_v ($\frac{1}{\overline{w}e}$ - $\frac{1}{\overline{w}n}$), equatorial launch is more economical

for
$$C_n$$
 (a - 1) = WC_V ($\frac{1}{We}$ - $\frac{1}{Wn}$), balanced costs



EFFECT OF LAUNCH SITE ON ACCUMULATED PAYLOAD AND TOTAL PROGRAM COST FIG. 11-9:

Normal inflation should be considered (3% 1 year)
Based on 60% of 100 vehicle flights for low altitude equatorial orbit
Saturn System Study - March 13, 1959, ABMA - Confidential

Notes: 1. 2. Reference: This equation is shown graphically in figure II-10. The curve illustrates the effects that vehicle costs, additional construction costs, and operating costs of an equatorial site have on the crossover. The plot shows that comparisons of equatorial vs non-equatorial launches must be made on an overall program basis.

ADDITIONAL COST OF LAUNCHING FROM AN EQUATORIAL SITE FIG. II-10;

TOTAL WEIGHT IN ORBIT - THOUSANDS OF POUNDS

III POTENTIAL EQUATORIAL LAUNCH SITES

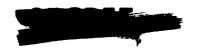


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Previous reports and proposals on equatorial launch sites for the most part have dismissed many potential launch sites because they fail to meet certain specifications which may not be rigidly defined. The fact that these reports and proposals recommend different sites suggests that different reporters place emphasis on contrasting requirements for such sites. For example, some governmental agencies incline to favor logistical distances while others appear willing to sacrifice proximity in order to have a site more favorably suited to the engineering requirements for a launch, such as azimuthal freedom or availability of fresh water.

Selection of the best launch sites should be made by carefully weighing the individual characteristics of each potential site against a standard set of specifications. The data presented herein will be sufficient to eliminate the less desirable sites and to suggest sites for more detailed study.

Excerpts from previous reports have been quoted for some sites. These excerpts, while valuable, could be misleading. Requirements for sites may have changed since the date of publication, or the originating agency might have had intended missions different from present and future proposed missions.

The west coasts of South America and Africa are not included in this report because an eastward launching, as would be used with a normal equatorial launch, necessitates flight over land. Besides the immediate fallout hazard, land recovery techniques for boosters are outside the scope of present U.S. experience. Ceylon was not considered in detail because of an unfavorable eastward launching range. Additionally, the government of Ceylon is fundamentally against military defense alliances1. If the site is to be used only for launching scientific exploratory vehicles, Ceylon might deserve study as to technical desirability and site negotiability.

Certain Pacific island groups offer literally hundreds of possible launch sites, but only the most promising are considered in detail. For instance, there are many potential sites in the Samoan Islands, but Tutuila is the only one considered herein because it has an excellent harbor (Pago Pago), while offering all the advantages of other local sites.

^{1&}quot;Consonant with its policy of nonalignment, the government is opposed to all military defense alliances, but actively participates in other forms of international cooperation." - The Worldmark Encyclopedia of the Nations, New York, Harper & Brothers, 1960, p.156.



Sample illustrations of islands are presented, but the presence of these does not necessarily indicate that they are the most desirable sites. These illustrations are not minutely detailed, but harbors, airfields, and major roads (solid lines) have been indicated. A large fold-out, figure III-1, is placed immediately after this section. It is intended to show the relative positions of the potential sites; but, to avoid clutter, it is not inclusive of all sites.

Major shipping lanes are indicated on the map by dotted lines. Preceding the map is table III-1, which contains various data for particular sites. This is intended to facilitate ready comparison. In some cases the chart may be misleading. For instance, a particular site might have an average rainfall of 200 inches, which would seem unfavorable for a launch site. However, this 200 inches of rain might fall in the late afternoons during April or May or at altitudes greater than 800 feet above sea level.

Distances from the United States are indicated on the chart. These distances, the stage fallout ranges eastward, and possible downrange tracking site distances in the discussions are approximations.

No attempt has been made in this report to present rigid launch site requirements, nor to evaluate those set forth in previous reports and proposals. The following general considerations should apply, however, to any mission or space vehicle launched from the equator:

- (1) Launches in all directions should be considered. An eastward launch is necessary.
- (2) Open water should extend downrange to allow safe booster fallout and to facilitate possible booster recovery.
- (3) The site should be of sufficient size not only for present missions but also for future growth. (When size is considered, offshore launch pads and other launch concepts should also be considered for expansion.)
- (4) Downrange tracking sites are required.
- (5) Proximity to the United States is desirable.
- (6) The political situation should be favorable.
- (7) Sea traffic downrange should not be heavy.
- (8) Facilities and fresh water are desirable.
- (9) Local labor and construction materials are desirable.



- (10) Soil and terrain should be suitable for construction purposes.
- (11) Existing docks, anchorages, and airfields would be advantageous.

This study was limited to local library facilities. The following publications have been valuable: Webster's Geographical Dictionary, Revised Edition, 1960 copyright; The Worldmark Encyclopedia of the Nations, 1960 copyright; Encyclopedia Britannica, 1960 copyright; Encyclopedia Americana, 1960 edition; The Columbia Encyclopedia, Second Edition, 1959 copyright; Geography of the Pacific, 1951 copyright, and various reports and proposals. (Abstracts of these reports and proposals are set forth in section IV.) It must be pointed out that inconsistencies are common among these sources, but only large deviations are pointed out in the text.

A. SOUTH AMERICAN AND ATLANTIC OCEAN SITES

1. BRAZIL

a. <u>Topography</u>. Brazil, the fourth largest nation in the world, has varied topography. The equatorial region of the coast is along the mouth of the Amazon Basin, and it has many bay-like indentations. The Amazon Basin, unlike most river beds, converges downstream, and then spreads out over a relatively narrow coastal plain. The Amazon has no true delta, and its mouth is embayed.

More detailed information is included in excerpts from previous reports.

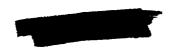
b. <u>History and Government</u>. Brazil's political history is complex. First claimed by Spain, and then yielded to Portugal, a move for independence culminated in 1822 when Pedro became emperor. A revolution established the Republic of the United States of Brazil. A constitution was made in 1891, closely following the constitution of the United States of America. Other constitutions were made in 1934, 1937, and 1945. From 1930 until 1945, Brazil was under dictatorship, or "disciplined democracy." In 1946, another constitution marked the Second Republic, and free elections were established.

Recently, there has been confiscation of U.S.-owned property in $\operatorname{Brazil.}^2$

c. <u>Population and Culture</u>. Brazil's population was estimated at near 65 million in 1959. The early Portuguese mixed freely



² For a discussion of current Brazilian-American affairs see: "How Safe is U.S. Property in Brazil?" <u>U.S. News and World Report</u>, 26 March 1962, pp. 43, 44, 45.



with the Indian natives, and now the people of Brazil have a distinct ethnic quality. There are small groups of Indians in the Amazon Basin and other interior regions. There has been large immigration from Europe, and, more recently, from the Orient. The language is a variety of Portuguese. Over 90 per cent of the people are Roman Catholics. There are small numbers of Buddhists, Jews, and Spiritualists.

- d. Climate. At Belem, near the mouth of the Amazon, the rainfall averages 86.0 inches annually. The average temperature is about 78° F, rarely deviating over 2° F. There are occasional drought areas in northeastern Brazil.
- e. <u>Transportation</u>. Brazil has both coastal and inland steamship transportation. There are excellent airways. Most of the 24,105 miles of railways are owned by the federal government. There are 290,500 miles of passable roads.
- f. Flora and Fauna. The Amazon Basin is the world's largest area of tropical forest. Rubber and hardwood trees are common. Brazil contains 50,000 vegetable species, and there are many varieties of tropical fauna.
- g. Agriculture and Industry. The economy of Brazil is based on agriculture, in spite of the fact that only 5 per cent of the land is cultivated. Coffee is the principal agricultural product. Cocoa, oranges, sugar, and tobacco are also important products.

Brazilian timber, especially the Amazon hardwoods, is of excellent quality, and is of important commercial value. Rubber trees are also important.

Brazil contains about 25 per cent of the world's iron ore. Once Brazil was the world's largest gold-producing country, but the mines have been exhausted. There are many exploitable metals and non-metallic minerals in Brazil.

In 1959, 110,000 motor vehicles were produced. Chemical and pharmaceutical manufacturing is increasing. There are many electric power plants in Brazil, and a nuclear power reactor has been constructed.

h. Stage Fallout Range from Belem

East: 4,000 miles to the coast of Africa.

West: land for about 3,000 miles over South America and the Galapagos Islands. (There is, however, about 1,000 miles of sparsely populated land.)

North: 3,200 miles to Nova Scotia and Newfoundland.



South: land for about 2,000 miles over Brazil. (About 1,000 miles of this land is sparsely populated.)

i. Possible Downrange Tracking Sites (Eastward)

St. Paul's Rocks (1º North latitude): 1,200 miles. Ascension (8º South latitude): 2,700 miles. St. Helena (16º South latitude): 3,100 miles. Tip of African Ivory Coast (5º North latitude): 2,800 miles.

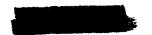
j. Excerpts from Previous Reports

- (1) "The political situation is unfavorable and the allowable azimuth traverse is inadequate. The extremely hot and humid climate would also be objectionable." Study on a Universal Launching Site for Space Missions, (Classified), Project Superb, ABMA, AOMC, 30 January 1959, p. 3.
- (2) "In figure 7³, the launch point is at the mouth of the Amazon River at the equator. With one or two exceptions, it is evident that in terms of Stage I impact, exit azimuths from 0 to about 105 degrees are acceptable. However, using exit azimuths from 105 to 180 degrees would necessitate immediate overfly of Brazil. Although the area overflown is thinly populated, this is not likely to be an acceptable situation to the Brazilian Government.

"Beginning with an azimuth of about 20 degrees, Stage II impact would occur in Norway, and on successive azimuths through about 122 degrees, impact could occur in Europe, the Balkans, and eastern Africa, through the Cape of Good Hope. Iceland is also within the impact zone at about 10 degrees; Greenland, between 0 and about 10 degrees. Although southerly exits are acceptable for Stage II impact from about 122 to 180 degrees, this sector is occupied by the Brazilian bulge with its attendant overflight problems. Under present launching and safety techniques these restrictions are so severe that it is inadvisable to give further consideration to this site.

"Other potential sites in the same region are subject to the same type of problems. The island of Fernando de Noronha (latitude 3° 49' S., longitude 32° 23' W.) would relieve the Brazil overflight and Stage I impact problems, but Stage II impact in Europe, the Near East, and Africa would seriously restrict the available exit azimuths. Westward launching from here or the mainland would entail direct overflight of South America and so intensify Stage I impact problems as to render westward launching impractical." Equatorial Launch Site Study (Classified), Space Technology Laboratories, Inc., Los Angeles, California, 25 March 1960, p. 29.

³ This figure was not reproduced.



(3) "A site in the State of Maranhao, Brazil was selected after studying map and air-photo information of the entire Brazilian coast between 2° north and 2° south latitude, (a straight line distance along the coast of about 580 miles). Much of this coastal area is swampland heavily clothed with mangrove and comprises a succession of points or promontories separated by bays or estuaries three to ten miles wide as they meet the Atlantic. Along the shore east of the Amazon mouth, swampland for eight to ten miles south of the Atlantic is interlaced with sizeable streams, 20 to 60 feet wide, 1000 feet to 3000 feet apart. No habitation or farm clearings appear in this area.

"Good high ground exists west of the North Channel of the Amazon north of the town of Macapa in the State of Ampa. But from this site polar launchings would be over land for a distance of 200 miles. Launchings to the east would be over two large islands (Janaucu, Caviana), known to have small fishing villages, so that control of these delta islands would probably be necessary.

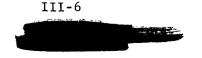
"Good high ground occurs at the east end of the shore line investigated, near where the $2^{\rm O}$ south latitude line meets the Atlantic coast. Photographs show some steep bluffs (height indeterminable) rising from the shore, rather than all swamp. Along the shore line between $2^{\rm O}$ 3' and $1^{\rm O}$ 40' south latitude launchings would be entirely over water to the north and to the east. Access to water would be from 5 to 15 miles long depending on detailed selection of the operational area. This is the site described in greater detail herein.

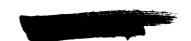
"Proposed site is from $1^{\rm O}$ 40' south latitude to $2^{\rm O}$ 5' south latitude; from $44^{\rm O}$ 15' west longitude. Photographs show many small clearings (5 to 30 acres) of cultivated land. A small town exists on the shore of one estuary. Ownership is unknown, assumed private plantations. On the $2^{\rm O}$ south latitude line, an estuary (Barro do Calhau) at the mouth of a small river (R. Arapiranga) has on its north shore a small town, covering about 0.4 of a square mile variously called Cuteiro or Outeiro. The number of families (information not available) which would require resettlement elsewhere is unknown. In addition, a considerable number of houses appear next to cultivated areas five to ten miles out from Cuteiro; these would probably require replacement.

"Transportation Distances by Water: From New York City-3150 miles. From Los Angeles - 5400 miles.

"Climatological and Meteorlogical Conditions: Temperature - Minimum 75°; Maximum 86°. Rainfall - Average annual: 84.8 inches. Wettest month: March (18.5 inches). Driest month: October (0.4 inches). Relative Humidity: 77-87 percent through year.

"Air movement: Prevailing winds generally from northeast and southeast. No storm data available.





"Health Conditions: High humidity results in discomfort, mildew, rust. World War II mosquito-control program, aided by USA, is being continued, but may not have been effective at this site, so malaria incidence may be high.

"Soil is fine grained to a depth of 20 feet or more before reaching bed rock, which with adequate drainage should provide fair to good foundation conditions.

"Regional Factors: (Nearby communities). Two sizeable cities nearest the site are Belem, capital of the State of Para (1950 population 225,218), 380 miles west of the site by water; and Sao Luis, capital of the State of Maranhao (1957 population 121,917), 40 miles southeast of the site by water. (No good overland connection to these cities is apparent.)

"Labor: Local labor, limited, must be supplemented.

"Construction materials: Limited local products must be supplemented by U. S. imported supplies.

"Food Supplies: Local products must be supplemented by imports from the U. S. $\,$

"Water Supply: Streams entering the Atlantic can provide ample water. Supply would be good chemically. Good quality water is also believed obtainable from wells 50 to 100 feet deep.

"Power and Fuel: Power must be generated locally from imported fuel.

"Transportation: No airfield or dock facilities exist. A natural entrance to potential protected harbor exists in the Cuma Bay (Baia de Cuma). Fifty feet of water is indicated at a point 15 miles out from possible dockage. Channel dredging will be required for the balance of the route to the dock site which is currently between 18 and 50 feet of water." - Technical Considerations and Plans (Classified), Project Horizon, Volume I, Department of the Army, 9 June 1957, p. 226.

Also, see the excerpt under Christmas Island for a comparison of Brazil and Christmas Island.

2. FRENCH GUIANA

a. <u>Topography</u>. French Guiana, on the northeast coast of South America, bordered by Brazil to the south and Dutch Guiana on the west, has approximately 200 miles of Atlantic coastline. This slanting coastline begins at about $5^{\rm O}$ North latitude and ends at about $7^{\rm O}$ North latitude.



French Guiana covers 34,740 square miles. The coastal zone, varying from 10 to 30 miles wide, is the only thickly inhabited section. Much of the coastal zone is swampy. Beyond the coastal zone are grassy plateaus, equatorial forests, and mountains.

A number of rocky islets lie off the coast northwest of Cayenne. Devil's Island, 8 miles off the coast and 30 miles north of Cayenne, covers about 16 square miles. It is dry, sandy, and torrid. Devil's Island was formerly a site of a penal colony, but it was abandoned in 1951.

- b. <u>History and Government</u>. The Dutch and French settled French Guiana about 1604. The British and Portuguese occupied the territory during the Napoleonic Wars, but it was restored to France. In 1947, it became an Overseas Department of France, sending one deputy and one senator to the French parliament.
- c. <u>Population and Culture</u>. The population was 27,863 in 1954, of which 80 per cent live along the coastal region, and of which 50 per cent live in Cayenne, the capital. The majority of the inhabitants are mixed white and Negro. There are small tribes of Indians in the interior.

Two large hospitals provide public health services, and the Pasteur institute combats endemic diseases. In 1959, there were 32 primary schools and several private schools.

Roman Catholic is the predominant religion, although there are various native cults.

- d. <u>Climate</u>. The average annual temperature is between 85°F and 90°F. It does not have much seasonal variation. There are usually trade winds along the coastal region, but the interior forests are muggy. Rainfall averages 130 inches annually at Cayenne, occuring in two well-defined seasons: December to July, and August to November.
- e. <u>Transportation</u>. Several major airlines have services to Cayenne. About 170 miles of the coastal roads connect the principal towns. Cayenne, Oyapoc, and Saint-Laurent-de-Maroni are the principal seaports.
- f. <u>Flora and Fauna</u>. Vegetation abounds. Mangroves grow along the coast. Vast forests in the interior contain large trees, ferns, orchids, and fungi. These forests contain teeming and varied animal life. Mosquitoes are a nuisance in all regions.
- g. Agriculture and Industry. Rum is the major export, followed by gold and hardwoods. There are large deposits of bauxite. Only a few areas along the coast are cultivated; agriculture is undeveloped.



- h. Stage Fallout Range. The stage fallout range is roughly the same as for the mouth of the Amazon Basin.
- i. <u>Possible Downrange Tracking Sites (Eastward)</u>. These sites are roughly the same as for the mouth of the Amazon Basin.

3. BRITISH GUIANA

- a. <u>Topography</u>. British Guiana is the westernmost of the three Guiana colonies. (Dutch Guiana is not considered in this report as a launch site because its coastline faces due north, and would not be ideal for eastward firing. It has, however, roughly the same topographical and climatic conditions as British and French Guiana.) British Guiana has an area of 83,000 square miles, of which 85 per cent is in forests. Much of the coastal strip, about 30 miles wide, is below sea level. Hilly lands and mountain ranges lie behind the coastal plain. The interior jungle is much the same as that described for French Guiana.
- b. <u>History and Government</u>. Holland occupied British Guiana for 200 years, fighting off the British, the French, and the Portuguese. It was ceded to Britain in 1815. In 1940, the United States leased military and naval sites for 99 years.

The political situation is likely to change: "The colony has been governed under precautionary special measures since 1953. It is administered by a governor, who presides over an executive council. There is a partly elective legislative council. In 1958, a committee was formed to recommend measures for restoring normal constitutional procedures. By 1960, arrangements were being made for eventual independence." 4

There has been recent political riots in British Guiana, and, as a result, independence has been delayed. "The British cabinet has decided that Guiana independence must be indefinitely postponed. Britain will now suggest a new 'dependent' status, with a long transitional period." 5

c. <u>Population and Culture</u>. The population in 1956 was 507,000, including 239,000 East Indians, 175,000 Negroes, and 57,250

The Worldmark Encyclopedia of the Nations, New York, Harper & Brothers, 1960, p. 1039.

⁵"Showdown," <u>Newsweek</u>, 5 March 1952.

Also See: "Georgetown Riots," New Republic, 5 March 1962.

[&]quot;Where Marxism Suffered a Setback," <u>U.S. News and</u> World Report, 5 March 1962.

[&]quot;Bring on the Tommies," <u>Time</u>, 24 February 1962.

[&]quot;Damned Either Way," Newsweek, 26 February 1962.

[&]quot;British Guiana," The Atlantic, July 1962.



mixed peoples. Georgetown, the capital, had a population of 120,000 in 1957. Most of the people, as in French Guiana, live along the coastal strip of lowlands. Approximately 80 per cent of the inhabitants are literate. There were 357 primary schools in 1957, but no higher education was offered. There were 151 doctors and 58 hospitals in 1957.

- d. Climate. Two wet seasons, from December to July and from August to November, bring much of the annual rainfall, which averages 90 inches along the coast and 59 inches in the interior. The temperature averages between 85° and 90° F.
- e. <u>Transportation</u>. There is an international airport near Georgetown, and there are charter services to local points. In 1958, there were 250 miles of coastal highways. Several rivers are navigable by ocean-going vessels for 60 to 90 miles inland.
- f. $\overline{\text{Flora and Fauna}}$. These are about the same as for French Guiana.
- g. Agriculture and Industry. The principal crops are sugar and rice. Timber, bauxite, diamonds, and gold are important exports. In 1957, there were six power plants producing 67,745,000 kwh. Trade unions have been organized.
- h. <u>Stage Fallout Range</u>. These data are about the same as for the mouth of the Amazon.
- i. <u>Possible Downrange Tracking Sites (Eastward)</u>. The downrange tracking sites are approximately the same as for the mouth of the Amazon.

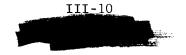
j. Excerpts from Previous Reports.

"This British Colony on the east coast of South America is further from the equator than would be desirable. The azimuth and range limitations here would be severe. Obtaining use of land for this purpose would probably be most difficult; also, the political situation (in case of war) is considered unfavorable." -- Study on a Universal Launching Site for Space Missions (Classified) ABMA, AOMC, Redstone Arsenal, Alabama, 30 January 1959, p. 3.

4. ST. PETER AND ST. PAUL'S ROCKS

St. Peter and St. Paul's Rocks, owned by Brazil, are a number of islets in the Atlantic Ocean at $1^{\rm O}$ North latitude and 540 miles from South America. Their area is small, not exceeding 1,400 by 700 feet.

Various insects, spiders, and sea fowl are the only life on the islet. Abundant fish are in the surrounding waters.





These islets are not large enough for an equatorial launch site, but they might be sufficient for a tracking station downrange of South America. It is possible that they might make a good foundation for a Texas-tower type launch complex, or a smaller Texas-tower type tracking station.

5. ASCENSION

- a. <u>Topography.</u> Ascension, an island of volcanic origin at 8° South latitude and 750 miles northwest of St. Helena, has an area of 38 square miles. There are plains 2,000 feet above sea level, and a huge elliptical crater rises 2,817 feet above sea level.
- b. <u>History and Government</u>. The island was discovered by the Portuguese, on Ascension Day, in 1501. It was uninhabited until 1815, when the British made a settlement at George Town. The island is a dependency of the British colony of St. Helena.

It has been used by Great Britain as a hospital base and coaling station. During World War II an airfield was built for a refueling base for transatlantic flights. In 1944 it was used by the U.S. Army for experimental hydroponic gardens.

- c. <u>Population and Culture</u>. The population in 1946 was 173, mostly St. Helenians of European origin.
- d. <u>Climate</u>. The climate is pleasant and notably healthful. The average rainfall is about 20 inches: March and April are the rainy months.
- e. <u>Transportation</u>. An airfield was established in World War II, and it has been used by the British as a naval base.
- f. Flora and Fauna. Ascension has little vegetation. There are great numbers of sea turtles, rabbits, wild goats, and sooty tern. Fish of excellent quality abound in surrounding waters.
- g. Agriculture and Industry. Cable and Wireless, Ltd., maintains a farm at Green Mountain for local food production. Most of the inhabitants collect phosphates and guano as an occupation.

h. Stage Fallout Range.

East: 1,600 miles to the coast of Africa.

West: 1,500 miles to South America.

North: 1,000 miles to the coast of Africa. South: 2,000 miles to Tristan da Cunha.

4,000 miles to the Antarctic.

i. Possible Downrange Tracking Sites (Eastward)

Coast of Africa: 1,700 miles.



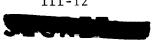
6. ST. HELENA

- a. Topography. St. Helena, a mountainous island of volcanic origin in the South Atlantic, has an area of 47 square miles. Its length is 10.5 miles and its width is 6.5 miles. Its position is 16° South latitude and 5° 21' West longitude. The highest elevation, on Mt. Actaeon, is 2,685 feet above sea level. It has a semicircular ridge of mountains. Streams and springs of pure water are plentiful.
- b. <u>History and Government</u>. St. Helena was uninhabited when it was discovered by the Portuguese in 1502. It was claimed by the Dutch in 1633, garrisoned by the British in 1659, captured by the Dutch in 1673, and retaken by the British. St. Helena is administered by a governor, an executive council, and an advisory council.
- c. <u>Population and Culture</u>. The population, mostly European, was about 5,000 in 1958. Jamestown, the capital, had a population of 1,568 in 1956. The inhabitants are almost all literate. There are 12 schools, and education is compulsory. The language is entirely English. There is a general hospital and a mental hospital.
- d. <u>Climate</u>. St. Helena has a pleasant climate, due to the southeast tradewind and the cold waters of the South Atlantic current. Rainfall varies considerably, having an annual maximum of 40 inches.
- e. <u>Transportation</u>. There is no established air service to St. Helena. In 1956, there were 64.5 miles of roads. The only good harbor suitable for large vessels is at Jamestown.
- f. Flora and Fauna. Rats, rabbits, and mice are the only undomestic animals. Fish are plentiful in the surrounding waters. Several types of sea birds are common, and land birds have been imported. Rare vegetation abounds, giving the island an exotic appearance.
- g. Agriculture and Industry. The economy is based on agriculture, although less than one-third of the land is suitable for cultivation. Hemp, flax, and potatoes are the principal crops. Processing hemp into rope and twine is the only industry.
- h. <u>Comments</u>. St. Helena, being 16° South of the equator, would not be an ideal equatorial launch site; it might, however, be of value as a tracking station for vehicles launched from South America.

B. AFRICAN SITES

1. SOMALIA

a. Topography. Somalia, on the east coast of Africa, extends from $12^{\rm O}$ North Latitude to $1^{\rm O}$ 39' South latitude. The northeastern region is a dry plateau with a maximum elevation of 8,250 feet. The





central region is a plateau with a maximum elevation of 2,250 feet. The southwestern region (roughly $6^{\rm O}$ North latitude to a little below the equator) is low agricultural and pasture land, irrigated by the Juba and Webi Schebeli rivers. Although much of the coastal area is covered with sand dunes, most of the country is covered with sandy clays or calcareous or gypseous rock.

b. <u>History and Government</u>. The Arabs, the Portuguese, and the Italians have held interests in Somalia at one time or another. British forces occupied Somalia in 1941. In November 1949, the United Nations General Assembly resolved that Somalia would receive its independence, with Italy acting as the administering authority. Somalia had its own government by 1960, and all governmental positions were held by Somalis. Elections were to be held every five years. The constitution was to follow the Italian or French type of parliamentary government.

In 1961, Somalia had border disputes with Ethiopia: "Little noticed by the daily press, the frontier fighting in Ethiopia's Harar province started when Emperor Haile Selassie ordered his regular army to make an example of the allegedly 'marauding' Somali nomads, who for centuries have been allowed to cross the frontier between Somalia and Ethiopia to graze their flocks. Smarting over the recent attempted coup which nearly ended his 3-year rule, Selassie was determined to put a stop to the pretensions of the new Somali nationalists who, ever since Somalia became independent last July, have laid claim to the eastern portions of his feudal kingdom. The Somalis hope to establish a Greater Somalia, incorporating some half million of their kinsmen who roam through the eastern third of Ethiopia. Selassie, meanwhile, claims a 300-mile strip of Somalia.

"The border scuffling was serious, but more important was the fact that two of Africa's independent nations -- states that usually make common cause against 'colonialism' -- were now close to war with each other." 6

c. <u>Population and Culture</u>. The population in 1958 was 1,330,000, of which approximately 95 per cent were illiterate. Populations of the largest cities were: Mogadishu (the capital), 80,000; Merka, 60,000; Villabruzzi, 16,000; and Baidoa, 16,000.

The Somalis are a mixture of peoples from the Middle East intermingled with various African tribal groups. The non-Somali population numbers about 35,000 Arabs, Pakistanis, Indians, and Italians.

No national language had been adopted in 1960. Dialectal Somali was spoken, but Arabic and Italian were used in the schools, and in most of the towns.

⁶Newsweek, January 16, 1961, pp. 39, 40.



There are a few catholic and protestant missions, but most of the people are Sunni Muslims.

In 1958, there were 160 primary schools, 4 secondary schools, 5 vocational schools, and 4 professional schools.

Tuberculosis, bilharziasis, and pulmonary disturbances are common. Malaria and intestinal diseases are endemic. Chemically and bacteriologically pure water is almost nonexistent, except in the larger towns. The supply of doctors is not adequate.

- d. Climate. There is little seasonal change in temperature in Somalia. The temperature averages about 80° F, but it varies from an occasional frost in the high plateau regions to 116° F along the coast. Heavy rains occur from March to May, and light rains from September to December. Average rainfall is about 11 inches, but it is irregular from year to year, and droughts are common. Rainfall varies from 20 inches annually in the plateau regions (sometimes reaching as high as 50 inches) to less than 3 inches along the coast. (In some coastal regions, where hills or dunes are near the shore, a narrow coastal belt may have 15 inches annually.) There are sporadic storms.
- e. <u>Transportation</u>. Somalia has 5,160 miles of roads, of which 400 miles are tarred. Most of the dirt roads are difficult to travel in rainy seasons. No inland waterways. Ocean-going vessels and air service are available. There are no internal railway facilities in operation. Much of the interior travel is by camel.
- f. Flora and Fauna. Somalia contains a great variety of large and small animals, many varieties of snakes and reptiles, and birds. Mangroves, kapok, and papaya grow along the rivers, plus several imported trees. Aloes, thorntrees, baobab, and other trees grow in the desert-like regions.

Mosquitoes and other insects are a nuisance in some seasons.

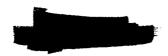
g. Agriculture and Industry. Livestock, corn, sorghum, legumes, and cotton are the principal agricultural products. There are no large timber-producing areas. Some fishing is done in the Indian Ocean, and Somalia has a tuna cannery. There are no exploitable minerals, but electric power is produced by imported petroleum.

Ninety per cent of the population are farmers or stock herders. Trade unions are established.

h. Stage Fallout Range from Somalia Coast (at 0° latitude)

East: 2,000 miles to Maldive Islands.

⁷ Disease caused by blood flukes.



West: The African mainland extends for 2,500 miles to the

South Atlantic.

North: Almost all land: Ethiopia, Saudi Arabia, Soviet Union.

South: 900 miles to Comora Islands.

2,700 miles to Crozet Islands and other minor islands.

NOTE: A space vehicle launched from 0° latitude on the Somalia coast would have to go directly south to avoid crossing over land; it would have to go between the coast of Mozambique and the Malagasy Republic, which are about 300 miles apart.

i. Possible Downrange Tracking Sites (Eastward)

Seychelles (4° South Latitude): 800 miles.
Suvadiva and Addu atolls (about 1° from the equator): 2,000 miles.

Chagos Archipelago (6° South latitude): 2,000 miles. Indonesia (astride the equator): 4,000 miles.

j. Excerpts From Previous Reports

- (1) "Approximately one hundred square miles, south of the navigable Guiba River, appears suitable for a launch site. This area is on level terrain, with limited rainfall. The Guiba River, however, would provide adequate water. Azimuth and range here is good for equatorial firings but only fair for polar firings as there would be danger of booster fallout on inhabited areas. The remote location relative to the United States would be a major disadvantage. Because of the logistic problem no further consideration is given to this location." Technical Considerations and Plans, (Classified), Project Horizon, Volume II, Department of the Army, 9 June 1959.
- (2) "The logistics problem here would be great, but not insurmountable." (The rest of this report's study is similar to the Project Horizon excerpt.) -- Study on a Universal Launching Site for Space Missions (Classified) ABMA, AOMC, Project Superb, Redstone Arsenal, Alabama, 30 January 1959, p. 4.
- (3) "The next potential site that seems worthy of consideration is in Somalia (formerly Italian Somaliland) in East Africa (see

Most sources give Juba as the spelling of this river; <u>Guiba</u> is the Italian spelling, and might appear in maps prepared before 1960. Whether the Guiba is navigable and whether it would provide adequate water is questionable: "There is no inland water transport water outside these centers (large cities) should be filtered, boiled, or chemically treated." - <u>The Worldmark Encyclopedia of the Nations</u>, New York, Harper & Brothers, 1960.

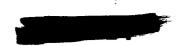


Figure 8). Exit azimuths from about 45 to 155 degrees appear feasible, except for a few azimuths which would be eliminated by potential Stage I impact on populated islands. In the region from 0 to 45 degrees, land impacts could occur in British Somaliland, Ethiopia (Abyssinia), and Saudi Arabia, in addition to water impacts in the Red Sea and the Gulf of Aden. In the sector from 155 to 180 degrees, the autonomous Malagasy Republic (Madagascar), a member of the French Community, is in the potential Stage I impact zone.

"Stage II impacts on azimuths from 0 degrees through about 125 degrees, could occur in Soviet Russia, People's Republic of China, the Republic of the Philippines, Republic on Indonesia, and Australia. From 125 to about 150 degrees, water impact would occur with impact on Antarctica at azimuths greater than 150 degrees.

"The same general type of situation would obtain for other potential launch sites, such as the Seychelles or Maldive Islands, in the Indian Ocean. With westerly launches from Somalia, Stage II impacts would occur in the North and South Atlantic; however, practically all Stage I impacts would occur in Africa. In addition, immediate African overflight for virtually all exit azimuths would occur. Thus, there is no reason to accept the launch velocity penalty of westward launch.

"Similarly, westward launch from West Africa does not offer compensating advantages, indeed North and South America become potential Stage II impact areas." -- Equatorial Launch Site Study, (Classified) Space Technology Laboratories, Inc. Los Angeles, California, 25 March 1960, p. 29.

2. KENYA

- a. Topography. Kenya, on the east coast of Africa between 5° North latitude and 5° South latitude, has a total area of 224,960 square miles. The northern portion is arid and nearly waterless. A tenmile wide coastal strip is low and marshy. A plateau in the southern portion has average elevations from 3,000 to 10,000 feet and Mt. Kenya is 17,040 feet above sea level.
- b. <u>History and Government</u>. Arabs and Persians settled on the Kenya coast in the seventh century. They were driven out by the Portuguese in the fifteenth century. Then the Arabs drove out the Portuguese in the eighteenth century. In 1895, Kenya became East African Protectorate under British domain, administered by a governor and various council members.

In 1952, the Mau Mau rebellion wrought political unrest and retarded Kenya's economic growth. Kenya has recently held conferences in England to negotiate its independence and British withdrawal.

This figure was not reproduced.

England maintained that she will not free the colony until she makes certain of a stable regime. Kenya's representatives agreed to accept the constitutional proposals set forth by Britain, and independence seems to wait only on the time required to prepare a satisfactory constitution. 10 There is internal political uncertainty in Kenya at the present time. 11

c. Population and Culture. In 1958, the population was 6,351,000, of which 6,080,000 were Africans. Kairobi, the capital, has a population of 250,000.

Schools, totaling over 5,000, are segregated for the Africans, Asians, Arabs, and Europeans.

The majority of the tribes are agriculturalists. Several languages are spoken, principally Bantu.

Mohammedanism is a popular religion in some coastal and northern communities, and a few communities are mostly Christian. The majority of the Africans, however, hold animistic beliefs.

d. Climate. Kenya's coastal area is hot and humid. Its average temperature is 80° F, but the plateau regions are cooler, having an average temperature of about 66° F. Rain in the plateau regions varies from 40 to 100 inches per year. Along the coast, rainfall is usually 10 inches per year.

The region north of the equator is hot and dry. Near Lake Randolf, rain does not occur for years at a time.

The northeast monsoon blows from December to March, and the southeast monsoon blows from May to October. The rainy seasons occur between the two monsoon seasons.

- e. <u>Transportation</u>. Kenya has regular coastal steamship service, and steamship service on Lake Victoria. There are 1 international airport, 13 smaller airports, and 18 landing fields. There are 22,072 miles of roads and 1,735 miles of railway.
- f. <u>Flora and Fauna</u>. Big game and smaller animals are plentiful. There are timber-bearing forests in the highlands, mangrove on the coast, and thornbush in the dry hinterland. Bamboo grows on the mountains except at heights above 10,000 feet.

¹⁰ Atlantic Monthly, June, 1962.

¹¹ For recent articles concerning Kenya's political scene, see: "Cooperation," Time, 20 April 1962, pp. 38, 39.

[&]quot;Last-Chance Conference," Time, February 23, 1962, p. 38.

[&]quot;New Order," Newsweek, 23 April 1962, p. 38.

Contini, J., "KANU, KANU and the Shadows of the Congo," The Reporter, 1 March 1962, pp. 30, 31, 32.



g. Agriculture and Industry. The economy is principally agricultural. Cereals, coffee, tea, meat, and dairy products are the most important crops.

The exploitable minerals include soda ash, salt, gold, diatomite, and small quantities of other minerals.

Various small industries exist, and hydroelectric power is produced on Maraqua, Tana, and Thika rivers. In 1958, 33 trade unions had been established.

h. Stage Fallout Range from Kenya

The stage fallout range from Kenya is approximately the same as that of the Somalia coast at $\mathbf{0}^{\mathrm{O}}$ latitude.

i. Possible Downrange Tracking Sites (Eastward)

The possible downrange tracking sites are approximately the same as those for the Somalia coast at $0^{\rm O}$ latitude.

C. INDIAN OCEAN SITES

1. SEYCHELLES ISLANDS

a. <u>Topography</u>. The Seychelles, a group of mountainous islands of volcanic origin in the Indian Ocean, constitute a British crown colony. The islands, at 4° South latitude and 56° East longitude, have an area of 156 square miles, of which 55 are covered by Mahe, the chief island.

Much of the terrain is mountainous: elevations range as high as 2,993 feet above sea level. There are low places, however, along the coast and in river beds. The islands are composed mostly of granite, and they are fringed by coral reefs.

- b. <u>History and Government</u>. The Seychelles were discovered by the Portuguese, who marked them on charts in 1502. They were established as a French colony in 1743. They were occupied in 1810 by the British, to whom they were ceded by the Treaty of Paris in 1814, and were made a dependency of Mauritius. The Seychelles became a separate crown colony in 1903. The executive council consists of a governor and six members, and the electorate comprises about 10 per cent of the total population.
- c. <u>Population and Culture</u>. A 1947 census showed a population of 34,632. Of the 92 islands, only 33 are inhabited, and one-third of the inhabitants live in Victoria on Mahe. The population is composed mostly of Europeans, Africans (introduced as slaves), and



Chinese. Nearly 90 per cent of the people are Roman Catholics. The language is a creole patois, based on French, but containing many Bantu, Indian, and English words.

Health conditions on the islands are good. Malarial fever is unknown, but hookworm is common.

There were 34 elementary schools, 3 secondary schools, and 1 vocational school in 1950. Education is free, but not compulsory.

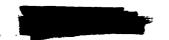
- d. Climate. On the coast the temperature varies from 68° F to 88° F. At higher altitudes, the temperature at night reaches 55° F. There is a well-defined dry season from May to October, during the southwest monsoon. The west-northwest monsoon blows from December to March. The winds are variable from April to November. The average rainfall is 90 inches along the coast, 120 inches at altitudes of 600 feet, and 150 inches at altitudes exceeding 2,000 feet. The Seychelles are outside the hurricane path.
- e. <u>Transportation</u>. Victoria's 3-mile wide harbor provides steamship connections, but there are no airfield facilities on the islands. There are about 75 miles of roads on Mahe suitable for motor travel. A regular broadcasting service is maintained.
- f. Flora and Fauna. The coral coastal regions abound in coconuts and mangroves. The granitic lands have the characteristics of tropical regions: palms, shrubs, and ferns grow luxuriantly. Rubber trees have been introduced. Timber trees (bois de fer and bois de natte) flourish on Silhouette Island.

Rats and bats are the islands' only mammals. Reptiles include various types of snakes, lizards, and turtles. There is a large variety of both land and sea birds.

g. Agriculture and Industry. Copra is the most important export. More than 3,500 acres of land are under forest, of which 25 per cent is commercial timber. Cinnamon and essential oils are exported. Breadfruit, the islands' staple food, is plentiful. Cassava, yams, sweet potatoes, and plantains are cultivated. The majority of the outlying islands are very fertile. Salted fish are exported. There are no manufactures or exploitable minerals on the islands (except for guano).

h. Principal Islands

(1) MAHE, the largest island, covers 55 square miles and has a population of 22,000. It is 17 miles long and from 3 to 7 miles wide. The principal city is Victoria, at which there is a good harbor. The highest point is 2,993 feet above sea level. The island is well watered.



- (2) <u>Praslin Island</u> is 8 miles long and from 1 to 3 miles wide. Its highest point is 1,260 feet above sea level. It covers 15 square miles. The population is about 2,000.
- (3) <u>La Digue Island</u> has a population of 1,000. It covers an area of 4 square miles, and its highest point is 1,175 feet above sea level.
- (4) <u>Silhouette Island</u>, roughly circular, covers an area of 8 square miles. Its highest point is 2,473 feet above sea level.

i. Stage Fallout Range from Mahe

East: 1,000 miles to Chagos Archipelago, then 3,000 miles to Indonesia.

West: 1,000 miles to the coast of Africa.

North: 1,500 miles to Saudi Arabia. (There might be danget of fallout hitting shipping traffic converging at the mouth of Red Sea.)

South: 300 miles to Agalea Island. 800 miles to Tromelin Island and Chargadoes Charjos Shoals. 1,000 miles to Mauritius and La Reunion islands, then clear until Crozet and Kerguelen islands, approximately 3,000 miles from Mahe.

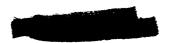
j. Possible Downrange Tracking Stations (Eastward)

Chagos Archipelago (about 6° South latitude): 1,200 miles. Suvadiva Atoll (about 0° 30' North latitude) and Addu Atoll (about 0° 30' South latitude: 1,300 miles. Indonesia (astride the equator): 3,000 miles.

2. MALDIVE ISLANDS

- a. <u>Topography</u>. The Maldive Islands are an archipelago of coral islets in the Indian Ocean about 400 miles southwest of Ceylon. The islands form a chain between 7° 6' North latitude and 0° 42' South latitude. The archipelago comprises some 2,000 islets, of which only 220 are inhabited, and covers a total area of 115 square miles. The islets vary from very small to five miles long. The larger islands vary from 6 to 20 feet above sea level. Many of the islands, especially in the southern region, contain freshwater lagoons.
- b. <u>History and Government</u>. The Maldive Islands were known to Ptolemy in A.D. 160. British protection of the islands was established in 1887 with Ceylon. The islands became a republic in 1953. The capital is on Male Island.

There was political instability in 1956, a reaction against the British re-establishing their air base on Gan (to serve as a major

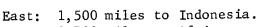


refueling station on the route between Great Britain and Australia). In 1959 a rebellion occurred in the southern Addu atolls when the Maldivian government sent a representative to Gan to tell the islanders to stop working for the British. New agreements were reached in February 1960: "Under the terms of an agreement initialed on 1 February 1960 and signed on 14 February 1960, the Maldivian government made a free gift to the UK of the use of Gan Island and other facilities in Addu Atoll for 30 years. A new agreement was drawn up redefining relations between the two governments and re-offering the obligations assumed by the UK for the defense of the Maldives. It allows for the conduct by the Maldivian government of its own external relations in the economic and cultural fields." 12

- c. <u>Population and Culture</u>. About 90,000 people populate the Maldive Islands. Maldivians are mixed with peoples from Western India and Arabia. Negro slaves were imported. Caucasian and Malayan peoples are also present. Although the early Maldivians were probably Buddhists, most of the people are now Sunni Muslims. The Maldivian language is similar to older Sinhalese (Ceylon).
- d. Climate. The climate is humid. The mean temperature is $81^{\rm O}$ F. The northeast monsoon causes mild, pleasant weather; the southwest monsoon, violent and very rainy weather. Generally, the southern atolls are subject to less severe storms than the northern islands.
- e. <u>Transportation</u>. Some of the larger islands, including Male, have wide roads covered with coral sand or crushed coral, although there were only 3 automobiles on the islands in 1953. Besides small boat travel, two steamships dock at Male. The British have an airfield on Gan in the southern Addu atolls.
- f. Flora and Fauna. Dense scrub covers the islands. Tropical trees flourish, although there is little commercial timber grown. Rats and flying foxes are the only mammals. There are many types of land and sea birds. Few snakes. The surrounding waters teem with fish, which account for 90 per cent of the islands' exports.
- g. Agriculture and Industry. After fishing, coir making is the next most important industry. Millet, corn, pumpkins, sweet potatoes, pineapples, sugar cane, almonds, mangoes, and coconuts are available.
- h. <u>Labor</u>. The British have employed 1,200 Pakistanis and 800 Maldivians on Gan Island. There are some excellent carpenters, masons, stone workers, and other craftsmen on the islands.

i. Stage Fallout Range from Male

The Worldmark Encyclopedia of the Nations, New York, Harper & Brothers, 1960, p. 637.



West: 1,700 miles to Africa.

North: 200 miles to Laccadive Islands and India.

South: 700 miles to Chagos Archipelago.

3.000 miles to Amsterdam and St. Paul Islands.

3,700 miles to Kerguelen Islands.

j. Possible Downrange Tracking Sites (Eastward)

Indonesia (astride the equator): 1,800 miles.

3. CHAGOS ARCHIPELAGO

- a. <u>Topography</u>. Chagos Islands, sometimes called Oil Islands, are a group of small coral atolls in the Indian Ocean 1,200 miles northeast of Mauritius Island. The archipelago consists of five main islets, with its center at 6° South latitude and 72° East longitude. Diego Garcia, largest of the Chagos Islands, lies 100 miles to the southeast of the main archipelago. The islands have a total area of 76 square miles. (More data are given under Principal Islands in this section.)
- b. <u>History and Government</u>. These British-owned islands are a dependency of Mauritius Island, which is administered by a governor, an executive council, and a legislative council.
- c. Population and Culture. The population of the Chagos Islands was 1,048 in 1944.
- d. <u>Climate</u>. Cyclones and strong winds occur between December and April, and the humidity is high.
- e. <u>Transportation</u>. The British maintained an air base on Diego Garcia during World War II.
- f. Flora and Fauna. Fish are abundant in the surrounding waters, and green turtles are numerous along the shores.
- g. Agriculture and Industry. Coconut oil is the chief product. Copra, fish, and guano are also exported. Swine and poultry are raised.
- h. <u>Principal Islands</u>. Diego Garcia is by far the largest of the islands. It is approximately 2.5 miles long and 6 miles wide, crescent-shaped, palm-covered, and encloses a lagoon. It is mainly of coral composition.

i. Stage Fallout Range from Diego Garcia

East: 2,000 miles to Indonesia. West: 1,000 miles to Seychelles.



North: 700 miles to Maldive Islands.

South: 2,300 miles to Amsterdam and St. Paul Islands.

3,000 miles to Kerguelen Islands.

j. Possible Downrange Tracking Stations (Eastward)

Indonesia (astride the equator): 2,000 miles.

4. INDIA

Trivandrum, on the west coast of the tip of southern India, has been considered as a launch site, according to "British to Back NASA Suggestion for Rocket Range Near Equator," Space Age News, 18 June 1962, p. 16. But, according to this article, "there are good reasons for having a site from which both sounding rockets and satellites can be launched and Trivandrum is located some 500 miles north of the equator and would involve firing over Ceylon."

No detailed study has been made of India for this report.

D. PACIFIC OCEAN SITES

1. MARQUESAS ISLANDS

- a. <u>Topography</u>. The Marquesas Islands, a group of 13 islands between latitudes 80 and 110 South and at approximately 1400 West longitude, have a total area of 376 square miles. The islands are of volcanic origin, and some of the mountains rise abruptly from the sea. The islands are characterized by a lack of coastal plains, and there are no surrounding reefs. The mountains have fertile and well-watered valleys. The highest point, on the island of Hiva Oa, is 4,134 feet above sea level.
- b. <u>History and Government</u>. The Marquesas were discovered in 1595 by Spain. France took possession in 1842, and the islands are in the territory of French Polynesia at the present, having Tahiti as the administrative capital. A council and assembly assist the French-appointed governor.
- c. <u>Population and Culture</u>. The population has decreased from 100,000 to 2,400 (1950 estimate). The people are pure Polynesian, once ritualistic cannibals. They occupy the only cultivatable and habitable areas on the islands.

The French provide public schools and medical aid. The language and general culture is Polynesian.

d. Climate. The mean annual temperature at sea level is 78° F, deviating only a few degrees with the seasons. Rainfall varies from 30 to 100 inches annually. Long droughts occasionally create famines.



- e. <u>Transportation</u>. Internal transportation is difficult because of knife-edge ridges. Much of the seashore is inaccessible because of high cliffs. Ships and a French airline make stops at the islands.
- f. Flora and Fauna. The high regions have dense forests. Thick underbrush grows in the valleys, and the plateaus are covered by grass, dense thickets of hibiscus, and ferns. Wild cattle roam the plateaus. Domestic livestock include cattle and pigs, and horses are raised.

There are no mammals on the islands other than those introduced by man. There are a few birds and lizards, and all fauna is sparse.

g. Agriculture and Industry. Copra is the major export. Breadfruit, yams, coconuts, mangoes, coffee, and vanilla are grown. Little of the land is suitable for cultivation.

h. Stage Fallout Range

East: 3,500 miles to Galapagos Islands and South America. West: about 700 miles clear, then numerous islands as far as Indonesia.

North: 4,500 miles to Canada and Alaska

South: the sparse islets of the Tuamotu Archipelago (200 miles from the Marquesas) extend 1,300 miles, then the way is clear to the Antarctica.

i. Possible Downrange Tracking Sites (Eastward)

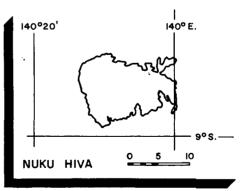
Galapagos Islands and South America: 4,000 miles.

j. Principal Islands.

(1) NUKU HIVA is the largest of the Marquesas. It has an area of 130 square miles. The population was estimated at 550 in

1950. It has a raised coastline of 70 miles, broken by 8 harbors. The interior consists of a plateau and high ridges (the highest point is 3,888 feet above sea level). The best harbor is on the north side of the island in Anoho Bay.

(2) UA PU (or Uapou), 25 miles south of Nuku Hiva, is 9 miles long and 8 miles wide, and its area is 40 square miles. The highest elevation is 4,040 feet above sea level. The population was estimated at 380 in 1950.

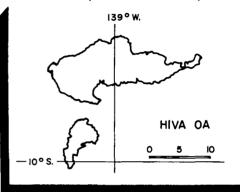




- (3) UA HUKA lies 30 miles east of Nuku Hiva. It is 9 miles long, 8 miles wide, and has an area of 30 square miles. Its high point is 2,805 feet above sea level. In 1950, the population was estimated at 150.
- (4) HIVA OA is 25 miles long and 8 miles wide. Its area is 125 square miles. Its population is 850 (1950 estimate).

The chief village is Atuana. There is a high central ridge down the island; its high point is 4,134 feet above sea level.

(5) TAHUATA, only three miles south of Hiva Oa, has an area of 20 square miles. It is 9 miles long and 5 miles wide. The population was estimated to be 250 in 1950.



- (6) FATU HIVA, 36 miles south of Hiva Oa, has an area of 25 square miles. It is 9 miles long and 4.2 miles wide. The island has a central mountain ridge (up to 3,670 feet above sea level), and a fertile valley. In 1950, the population was estimated to be 200.
- (7) EIAO, 56 miles northwest of Nuka Hiva, has an area of 20 square miles. It is 8 miles long and 4 miles wide. Its high point is 2,000 feet above sea level. Now uninhabited, it was formerly a place of exile for French convicts.
- (8) HATUTU, 10 miles northeast of Eiao Island, has an area of 7 square miles. It is 5 miles long and 2 miles wide. Its highest elevation is 1,380 feet above sea level. It was uninhabited in 1950.
- (9) MOHOTANI has an area of 6 square miles, a length of 5 miles, and a width of 1.5 miles. Its high point is 1,700 feet above sea level. It was uninhabited in 1950.

2. GILBERT AND ELLICE ISLANDS BRITISH COLONY

a. <u>Topography</u>. The Gilbert and Ellice Islands British Colony contains 37 coral atolls and islets scattered over a rectangle of 1,000,000 square miles of sea between latitudes of 0° and 11° North and East longitudes of 172° and 180° . These islands have a total area of 342 square miles. (Areas of specific islands are set forth under Principal Islands in this section.)

The islands are composed of coral formations (except for Ocean Island, which is of volcanic origin). They are low, seldom





over 15 feet above sea level. The soil, coral sand, is only a few inches deep on the majority of the islands. They have no rivers.

b. <u>History and Government</u>. Most of the islands became a British protectorate in 1892. They were made a colony in 1915, administered by the Western Pacific High Commission at Tarawa. The islands were occupied by Japan during World War II.

The following islands, either under joint United Kingdom and United States administration or ownership is disputed, are included in this group: Malden, Canton, Enderbury, Jarvis, Howland, Baker, Christmas, and Starbuck. Palmyra Island and Kingman Reef, possessions of the United States, are considered in this section, along with Nauru, an island included in the Trust Territory of Australia. Also, Penrhyn Island, a dependency of New Zealand, is included. These deviations from straight British domain are noted under particular island headings.

c. <u>Population and Culture</u>. In 1958 the population was estimated at 43,482. The people are mainly Melanesians, with a few Micronesians, Polynesians, Europeans, and Chinese. Tarawa (3,852 in 1957) and Ocean Island (2,060 in 1957) have the largest population.

There were 5 doctors in 1958, and all the islands with a resident population have a hospital, its size depending on population. School is compulsory, and 90 per cent of the population is literate. Many of the natives have been converted to Christianity.

- d. Climate. The temperature varies from $80^{\rm O}$ F at noonday, and it sometimes drops to $70^{\rm O}$ F at night. Extremes recorded are: $101^{\rm O}$ F maximum and $68^{\rm O}$ F minimum. The annual rainfall averages 40 inches at the equator to 100 inches in the northern Gilberts to 120 inches in the Ellice Islands. The area is subject to hurricanes. The climate throughout the Gilberts is pleasant but monotonous, and although the rainfall is considered heavy, destructive droughts occur about every seven years. During these droughts, little fresh water is available.
- e. <u>Transportation</u>. Ocean, Tarawa, Fanning, and Christmas islands have seaports. There are few motor vehicles. There is an international airport at Canton Island, but there is no inter-island air service.
- f. Flora and Fauna. This information is given under Principal Islands in this section.
- g. Agriculture and Industry. Copra is the only commercial agricultural product. Phosphate mining, concentrated on Ocean Island, is the only industry.

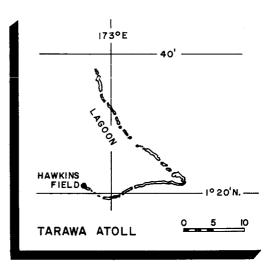


h. Principal Islands

(1) TARAWA ATOLL

(a) General.

Tarawa, capital of the British colony of Gilbert and Ellice Islands, at 1° 30' North latitude, has a total area of 7.7 square miles. Tarawa comprises a chain of sandy islets around a lagoon 18 miles long and with a maximum width of 13 miles. There is a good anchorage at Betio. Harbor facilities are being restored. Only a limited amount of fresh water is available. Flora includes coconut palms and taro plants.



(b) Stage Fallout Range.

East: 700 miles to Howland and Baker Islands.

2,000 miles to the Line Islands.

West: 1,300 miles to Kapingamarangi Atoll.

A narrow way for 2,500 miles along the

equator.

North: Several of the Marshall Islands, slightly to the west, out to about 800 miles; then

clear (except for the small Midway Islands

2,000 miles off) until Siberia.

South: Gilbert islets out to 400 miles; then

Ellice islands, and other island complexes are scattered all the way to New Zealand.

(c) Possible Downrange Tracking Sites (Eastward)

Howland and Baker Islands (about 1° North latitude): 700 miles.

Jarvis Island (0° 32' South latitude): 1,900 miles. Christmas Island (2° North latitude): 2,000 miles.

(d) Excerpts from Previous Reports.

"These islands 13 are not considered adequate for a launching base of the anticipated size necessary for future space missions. Also, the equatorial firing range would cover the inhabited

 $[\]overline{^{13}}$ The Gilberts, of which Tarawa Atoll is typical.

on a Universal Launchine Sit

Line Islands." -- Study on a Universal Launching Site for Space

Missions, (Classified), Project Superb, ABMA, AOMC, Redstone Arsenal,
Alabama. p. 3.

(2) TABITEUEA ISLAND

- (a) <u>General</u>. Tabiteuea Island (an atoll) is about 50 miles long and lies approximately 80 miles south of the equator (at 10 South latitude and 175^{0} East longitude). The atoll has a total land area of 19.0 square miles. It has five villages, and its population in 1936 was 3,856.
- (b) Stage Fallout Range and Downrange Tracking Sites are about the same as for Tarawa Atoll.
- (c) Excerpts from Previous Reports set forth for Tarawa Atoll apply to Tabiteuea Island.

(3) BERU ISLAND

- (a) <u>General</u>. Beru Island, an atoll, is 11 miles long and has a total land area of 8.2 square miles. Its latitude is 10 South; its longitude, 176^{0} East. The population in 1936 was 2,468. It serves as a missionary school and headquarters.
- (b) <u>Stage Fallout Range and Possible Downrange</u> <u>Tracking Sites</u> are approximately the same as for Tarawa Atoll.
- (c) Excerpts from Previous Reports set forth under Tarawa Atoll will apply to Beru.

(4) ARORAE ISLAND

- (a) <u>General</u>. Arorae Island, at 3° South latitude and 177° East longitude, has an area of 5 square miles and a population of 1,550.
- (b) <u>Stage Fallout Range and Possible Downrange</u> Tracking Sites are approximately the same as for Tarawa Atoll.
- (c) <u>Excerpts from Previous Reports</u> set forth for Tarawa Atoll will apply to Arorae Island.

(5) NUKUNAU ISLAND

(a) <u>General</u>. Nukunau Island, at 1° South latitude and 177° East longitude, has a length of 8 miles, a width of 1.5 miles, and an area of 7 square miles. The population in 1947 was 1,592.





- (b) <u>Stage Fallout Range and Possible Downrange</u> Tracking <u>Sites</u> are approximately the same as for Tarawa.
- (c) Excerpts from Previous Reports set forth for Tarawa will apply to Nukunau Island.

(6) KURIA

- (a) General. Kuria has an area of 4.5 square miles. It is located at 2° North latitude and 173° East longitude. It is low, flat, near sea level, and covered with coconut palms and scrub. The average rainfall is 50 inches annually. Its population is about 300.
- (b) <u>Stage Fallout Range and Possible Downrange</u> Tracking <u>Sites</u> are approximately the same as for Tarawa.
- (c) Excerpts from Previous Reports set forth for Tarawa apply to Kuria.

(7) ARANUKA ATOLL

- (a) General. Aranuka Atoll, at 2° North latitude and 173° East longitude, has an area of 6.0 square miles. Flora includes coconut palms and low scrub. The terrain is low and flat, near sea level. Average annual rainfall is 50 inches. The population is about 366.
- (b) <u>Stage Fallout Range and Possible Downrange</u> Tracking Sites are about the same as for Tarawa Atoll.
- (c) <u>Excerpts from Previous Reports</u> set forth for Tarawa will apply to Aranuka Atoll.

(8) ONOTOA ATOLL

- (a) General. Onotoa Atoll, at 2° South latitude and 176° East longitude, has an area of 5.2 square miles and a population of 1,490.
- (b) <u>Stage Fallout Range and Possible Downrange</u> Tracking Sites are about the same as for Tarawa Atoll.
- (c) <u>Excerpts from Previous Reports</u> set forth for Tarawa will apply to Onotoa Atoll.

(9) OCEAN ISLAND

(a) $\underline{\text{General}}$. Ocean Island, at 0° 52' South latitude, is 160 miles east of Nauru Island. Its area is 2 square



miles. Copra and large amounts of phosphate lime are exported; but a barrier reef hinders transportation. The population was 2,060 in 1948.

(b) Stage Fallout Range

East: Gilbert Islands

within 500 miles.

1,000 miles to

Howland Island, Baker Island, and the Phoenix Island complex. 2,500 miles to

the Line Islands.

800 miles to Kapingarmarangi Atoll. A West:

narrow way for about 2,500 miles along

the equator.

300 miles to Marshall Island complex. North:

1,500 miles to Wake Island, then clear to

Siberia.

(c) Possible Downrange Tracking Sites (Eastward)

Gilbert Islands: 300 to 500 miles Howland and Baker Islands (about 10 North latitude): 1,000 miles. Christmas Island (2° North latitude): 2,500 miles.

-0050's

169°35'E.

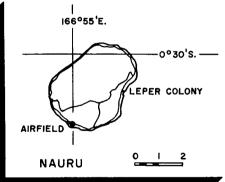
OCEAN ISLAND

(10) NAURU

(a) General. This oval shaped island is 8.2 square miles in area, and its highest point is 225 feet.

tude is 0° 31' South and it lies about 300 miles east of the Gilbert Islands. Nauru is surrounded by a reef, and it has no harbor.

The population was 4,308 in 1958, the majority being Nauruan natives. The standard of living is good, and motor vehicles are numerous. There were six primary schools (compulsory) and one secondary school in 1958.



An Australian-appointed administrator governs the island, with assistance by a popularly elected council consisting of nine members.

Much phosphate is exported, although a barrier reef hinders transportation. Ships are anchored outside the reef and the phosphate is loaded by a cantilever-belt conveyor system.

(b) Stage Fallout Range and Possible Downrange Tracking Facilities are about the same as for Ocean Island.

(11) NONOUTI ISLAND

(a) <u>General</u>. Nonouti Island, an atoll, is in the central portion of the Gilbert Islands at 0° 40' South latitude and 174° East longitude. The atoll has a length of 24 miles, a maximum width of 10 miles, and an area of 9.9 square miles. It is low and flat and level. Flora include coconut palms and low scrub. In 1936, the population was 2,084.

Temperatures vary from 78° F to 90° F. Annual rainfall averages 43 inches, but it is variable from year to year.

The lagoon channel is 4 fathoms. There is good anchorage, but the island has no airstrip.

- (b) <u>Stage Fallout Range and Possible Downrange</u> <u>Tracking Sites</u> are approximately the same as for Tarawa Atoll.
- (c) Excerpts from Previous Reports. "The configuration of Nonouti Atoll (see table 5 and figures 11 and 12) 14 is considered to be the best of all the considered sites for adaptability as a launching site. Nonouti also is very near the equator, being only 40 minutes to the south. However, Nonouti has a native population of about 1,900 persons for whom safety arrangements would have to be considered. -- Selection of an Equatorial-Launch Site, Technical Memorandum No. PMR-TM-60-13, Pacific Missile Range, Point Mugu, California, 28 December 1960, p. 33.

(12) ABEMAMA

(a) <u>General</u>. Abemama, a low, flat coral atoll near sea level, is located in the Gilbert Islands at 0° 21' North latitude and 174° East longitude. It has a total land area of 6.6 square miles. The population in 1936 was 841. Flora include low scrub and coconut palms.

There is good anchorage in the lagoon (35 feet deep). During World War II, an airfield was built, but it has since been planted in coconut palms.

Annual rainfall is about 50 inches. Hurricanes are infrequent.

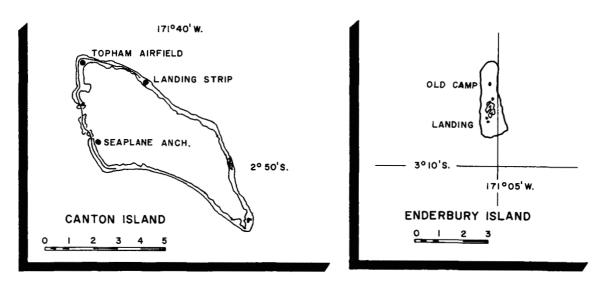
(b) <u>Stage Fallout Range and Possible Downrange</u> Tracking Sites are about the same as for Tarawa Atoll.

¹⁴ These tables and figures were not reproduced.

(c) Excerpts from Previous Reports, "The major advantage of using Abemama Atoll (see table 4 and figures 9 and $10)^{15}$ as a remote, equatorial-launch site is that it lies only 21 minutes north of the equator. Furthermore, its configuration is suitable for the launch complex. A major disadvantage is seen, however, in the location of Kuria and Aranuka Atoll immediately downwind from Abemama. Native inhabitants of these two places would have to be relocated as a safety measure." -- Selection of an Equatorial-Launch Site, Technical Memorandum No. PMR-TM-60-13, Pacific Missile Range, Point Mugu, California, 28 December 1960, p. 33.

(13) CANTON AND ENDERBURY ISLANDS

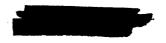
(a) General. Canton Island, at 2° 46' South latitude and 171° 43' West longitude, has a land area of 4.0 square miles and a lagoon area of about 20 square miles. It has a 7,000 by 150 foot airstrip with a 1,900 foot overrun. A reef fringes the island, but there is a natural harbor on the west side of the lagoon. Flora includes grass and low scrub, and the topography is low and flat. Annual rainfall is about 19 inches, but variable. The average annual temperature is 84° F. The population is about 340 persons. There is a hospital and administration building.



Enderbury Island, an uninhabited atoll of rectangular shape, 37 miles southeast of Canton, has an area of 2.3 square miles. There are no seaplane facilities and no good anchorage; its lagoon is merely a shallow pool.

In 1939, both islands were made a condominium of the United States and the United Kingdom.

¹⁵ These figures and tables were not reproduced.



(b) Stage Fallout Range

East: 800 miles to Jarvis Island.

1200 miles to Christmas, Malden, and Starbuck islands, then clear 5,000 miles to the

Galapagos Islands and South America.

West: 800 miles to Gilbert Islands.

North: 2,000 miles to Hawaii and Midway Islands. South: Various island groups for 1,300 miles.

(c) Possible Downrange Tracking Sites (Eastward)

Jarvis Island (0° 32' South latitude): 800 miles.

(d) Excerpts from Previous Reports. "Many attractive features that make this atoll (see table 2 and figures 5 and 6)¹⁶ the best contender for use as a remote, equatorial-launch site include the following:

- 1. Airfield and harbor facilities are in operation, and a sheltered seaplane basin is usable for recovery operations.
- 2. Weather conditions are best for the sites considered.
- 3. Early acquisition appears feasible without major difficulty.

"Also of possible value is small, uninhabited Enderbury Atoll, approximately 37 nautical miles east-southeast of Canton, which could be used as an expansion area for hazardous operations (possibly by using mobile facilities).

"The major disadvantage in using Canton as a launching site is the distance to its proposed northern (down-range) tracking site, Johnston Island. This 1,200-nautical-mile distance may limit the acquisition of launch-phase tracking data to operations in which higher-altitude orbital trajectories are used. Launches to the south appear possible if heading variations are restricted to small values. Figure 13¹⁷ envisions a fully developed fixed/mobile launching complex on Canton Atoll." Selection of an Equatorial-Launch Site, Technical Memorandum No. PMR-TM-60-13, Pacific Missile Range, Point Mugu, California, 28 December 1960, page 30. (This report concluded that Canton Atoll appeared to be the best available site for a remote, equatorial launch facility. Malden, Starbuck, Penrhyn Atoll, Abemama Atoll, Kuria, Aranuka Atoll, Nonouti Atoll, Tabiteuea Atoll, Beru, Nukunau, Onotoa Atoll, and Arorae islands were also considered.)

¹⁶ These tables and figures were not reproduced.

 $^{^{17}}$ This figure was not reproduced.



(14) MALDEN ISLAND

(a) <u>General</u>. Malden Island, 4° 31' South latitude and 155° 1' West longitude, has an area of 35 square miles. ¹⁸ It is 108 miles northwest of Starbuck Island and 275 miles southeast of Jarvis Island. It is flat, low, and saucer-shaped. Flora is sparse, consisting of low bushes and grass. There is no harbor, airstrip, or other facilities, and no fresh water is available. It is uninhabited. The temperature varies from 72° F to 92° F. Annual rainfall averages 27 inches, but it is variable.

(b) Stage Fallout Range

East: 5,000 miles to the Galapagos Islands and

South America.

West: 900 miles to Phoenix Islands.

2,000 miles to the Gilbert Islands.

North: 600 miles to Christmas Island.

1,700 miles to Hawaii.

(c) <u>Possible Downrange Tracking Sites</u>. There are no downrange tracking sites near the equator for 5,000 miles. The Marquesas Islands, between 8° and 11° South latitude, are about 1,000 miles southeast from Malden Island.

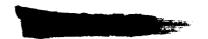
(d) Excerpts from Previous Reports. "The major advantage of using Malden Island (see table 3 and figures 7 and 8)¹⁹ as a remote, equatorial-launch site is that it is uninhabited. The major disadvantage is that it has no existing facilities. Other currently available information about Malden Island is questionable as to accuracy. Reliable sources issue figures of land and lagoon area that are approximately twice those obtained from scaling charts. The actual configuration of the site also is in conflict. Consequently, updated surveys are required to assess the adaptability of Malden as a potential site for a launch complex." -- Selection of an Equatorial-Launch Site, Technical Memorandum No. PMR-TM-60-13, Pacific Missile Range, Point Mugu, California, 28 December 1960, p. 30.

(15) STARBUCK ISLAND

(a) <u>General</u>. Starbuck Island, at 5° 35' South latitude, is uninhabited and treeless. It lies 108 miles southwest of Malden Island. Its length is 5.5 miles, its maximum width is 2 miles, and its elevation is about 15 feet. Its area is 8.1 square miles.

 $[\]overline{18}$ Note the comments concerning Malden Island's area in the excerpt from previous reports.

¹⁹ These tables and figures were not reproduced.

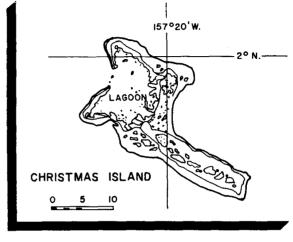


(b) Stage Fallout Range and Possible Downrange Tracking Sites are about the same as for Malden Island.

(16) CHRISTMAS ISLAND

(a) General.

Christmas Island, a present nuclear test site, is located at 1° 59' North latitude and 157° 30' West longitude. Its area is 160 square miles. Most of the island is covered with sand hills, up to 40 feet above sea level. There are scattered lagoons. Flora consists of coconut palms and scrubby trees.



Three wells supply limited water suitable for drinking.

(b) Stage Fallout Range

East: 4,500 miles to Galapagos Islands and South

West: 1,300 miles to Howland and Baker Islands.

2,000 miles to Gilbert Islands.

North: Fanning, Washington, and Palmyra islands lie from 200 to 400 miles to the north-

east. 1,300 miles to Hawaii.

South: 600 miles to Malden and Starbuck islands.

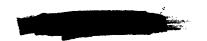
Several other islands and inland groups

for 2,000 miles.

(c) <u>Possible Downrange Tracking Sites</u>. There are no downrange tracking sites for 5,000 miles.

(d) Excerpts from Previous Reports. "The center of this Pacific coral atoll is approximately 10 59 north latitude and 1570 30' west longitude. It is approximately 160 square miles in area, of which about 100 square miles are usable. Average elevation is approximately 10 feet above sea level with a few sand hills 20-40 feet high. It is administered by the British as a part of the Gilbert and Ellice Islands Colony; however, the United States also claims sovereignty. The chief use of the island in the past has been for coconut plantations. There are about 60 permanent inhabitants of the island and, at present, there exists a British headquarters for nuclear tests. The British have maintained a radio station (now includes daily weather service) on the island since 1937.

"Transportation distances by water: From New York City - 7300 miles. From Los Angeles - 2900 miles.



"Climatological and Meteorological Conditions: Temperature - Minimum 74°; Maximum 91°. Rainfall - Average annual: 22 inches. Has varied from 10 to 300 inches. Relative Humidity - normal. Air movement - prevailing winds from east and southeast with northeast in March and May. No hurricanes or severe storms. Health conditions - near ideal living conditions; free from malaria.

"Soil and Foundation Conditions: At a comparatively shallow depth, a fairly hard stratum of sandstone occurs, still in formative stage. Two test pits indicated:

Test 1

Top 8 inches - sandy loam

Next 12 inches - 80 percent coral, 20 percent sand

Next 20 inches - 10 percent coral, 90 percent sand

Test 2

Top 12 inches - 80 percent sandy loam, 20 percent coral Next 12 inches - 90 percent coral, 10 percent white sand

"Regional Factors: Nearest city for logistic support and for normal 'social outlets' is Honolulu, Hawaii (1950 population 497,000), 1160 miles away.

"Labor - No source of local labor.

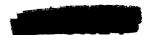
"Construction materials - Except for sand and possibly coral aggregate, all material must be shipped in.

"Food supplies - All food must be shipped in.

"Water supply - It is believed that an adequate quantity of water can be collected just above the sandstone stratum and from fresh water lagoons.

"Power and fuel - Power must be generated locally from imported fuel.

"Transportation - Dock Facilities. London Harbor, a protected natural harbor on the west side of the island, has landing facilities, quays, and several piers. Main harbor entrance has a depth varying from 12 to 18 feet (mean tide range about two feet). Anchorage facilities exist for several coasters in the open roadstead off the lagoon in depths of approximately 100 feet. Four mooring buoys (one telephone-equipped) facilities consist of over 1000 feet of wharfage; berthing length 330 feet, five piers, wharf derrick, and industrial tracks on two wharves. Channel dredging would be required for a distance of about 10 to 12 miles to the dock site.



"Airfield Facilities: Two existing all-weather runways, one 6890 feet long, the other 5050 feet long, both 200 feet wide of two-inch asphalt on hard-packed coral, would require lengthening and strengthening to be adequate for proposed operational use. Support facilities of all categories would have to be added." -- Technical Considerations and Plans, (Classified), Project Horizon, Volume II, Department of the Army, 9 June 1959, p. 221.

The following comparison of Christmas Island to Brazil is also quoted from the Project Horizon report:

"CHRISTMAS ISLAND VERSUS BRAZIL

"l. Availability

"Negotiations with a friendly power, assuming a priority situation, might provide right of entry for surveys within 60 days and for construction within six months. British plans for Christmas Island in connection with nuclear tests and any facilities planned in connection with the Pacific Ocean missile firing ranges are not known, but will undoubtedly affect the negotiations and perhaps the availability of this site. Except for political considerations, no problems in attainment of the Brazil site are foreseen. Relocations may delay access to some areas but, with cooperation by the Brazilian Government, no serious delays are anticipated.

"2. Construction Problems

"The time required for mobilization and build-up to support the construction effort will vary depending upon the site selected. The construction program as scheduled on the accompanying chart (Fig. II-73)²⁰ is contingent upon receiving authorization to proceed with planning and design by 1 July 1959, obtaining right of entry for surveys by 1 September 1959 and completion of site negotiations in time for construction operations to begin on 1 January 1960. Construction costs, facilities and schedules shown in this report for Brazil would be quite similar to those shown for Christmas Island.

"If Christmas Island is selected for the location of the launch site, 15 months on the site will be the minimum required for completion of the dredging operations, erection of batching plants, and the construction of docks, port facilities, construction camp, and the minimum essential roads and utilities. Except for local aggregate sources, all construction materials must be shipped in. This build-up or Phase I construction period is absolutely essential to achieving the construction capability of the magnitude required. (Construction Phases described in this section refer to Fig. II-73²¹ and are not

²⁰ Not reproduced.

²¹ Not reproduced.

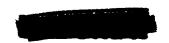


the overall Project HORIZON program phases). Beginning shortly after completion of Phase I, construction placement at a rate of some \$7,000,000 per month will be necessary and will require a construction force ranging between 2000 and 3000 persons. The existence of an airfield and minor dock facilities at this site will be of considerable value during the initial operations. Difficult dredging and excavation conditions are anticipated. However, the site should provide good road base material and hardstanding for rapid expansion of the area of operations. Here also the pleasant climate, moderate rainfall and freedom from insect pests will be an aid to rapid construction. At this site, construction of the camp and other basic supporting facilities can proceed simultaneously with construction of the permanent port facilities, using the existing harbor and wharfing.

"In the event the Brazil site is chosen, it is estimated that an additional six months construction time will be required through the Phase II period, which provides for task launch capability. The construction problems initially are greater in Brazil and there is no satisfactory access to the site by land, sea or air to support even limited operations. A beach head operation with personnel, equipment and materials landed by barge or LST will be required until temporary unloading facilities can be provided. Airfield construction will be an additional early priority item to support both construction operations and the initial launching operations. Relocations are expected to delay access to certain areas and may also require additional construction as well as monetary settlements. Although many small clearings are noted in aerial photographs, much of the area is dense jungle. Mapping, site surveys, and other investigations will require more time. Construction operations such as clearing, drainage, sanitation measures, and road construction will require a much greater expenditure of effort than would be required at Christmas Island. Likewise, the heavy rainfall, mud, insects, malaria and the hot, humid climate will all contribute to the generally unfavorable construction environment. Not only will a greater expenditure of effort be required to place the same amount of work, but site and climatological conditions are expected to present more difficult design problems in certain instances, with a corresponding increase in design time and construction. Although all construction materials, equipment and labor will be brought in initially, the local potential for construction and logistic support will be developed as rapidly as practicable. Past experience indicates that Brazilian workers learn readily but a training program will be required to develop an efficient labor force.

"3. Operational Considerations

"Climatic conditions at Christmas Island will be more favorable for sustained operations. The Brazil site, however, should offer some advantages from the standpoint of tracking. Land-based tracking stations are possible downrange from the Brazil site, whereas tracking ships will be required if Christmas Island were selected."



"4. Construction Costs and Schedule

"Construction costs of the launching facilities and all supporting facilities shown in Chapter $VIII^{22}$ are based on the Christmas Island site, because they could not be made available on the Brazil site at this time due to lack of information. Facilities totaling \$426,000,000 for design and construction will be located generally as shown on the land use study, Fig. II-69.23 Maintenance and operating costs are not included.

"Excluding real estate and relocation costs, which cannot be evaluated at this time, it is estimated that construction costs in Brazil will be about 10% less. This savings anticipates a reasonably good supply of labor and the increasing development of local capabilities, and would be greater except for the less favorable design and construction conditions discussed in paragraph 2 preceding.

"5. Growth Potential

"The Brazil site appears to have the potential for any fore-seeable growth or expansion of facilities. Conditions are, likewise, favorable for a progressive increase in local capabilities for construction and logistic support. As previously discussed, the usable land area on Christmas Island will not exceed 100 square miles. While this area is sufficient to accommodate installations several times as extensive as planned for this program, it could not accommodate nuclear propelled (booster) vehicles, unless nearby JARVIS Island is used for this purpose.

"6. Conclusions

"Both Christmas Island and Brazil satisfy sufficiently the general criteria for site selection to be acceptable for an equatorial launch site. After all these criteria are considered and the comparison made, a choice as to which is the best site can be made only after some relative importance or priority scheme is set up for the various desirable characteristics. It is believed that ultimate site selection will be governed by cost and early availability."

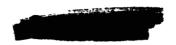
(17) JARVIS ISLAND

(a) <u>General</u>. Jarvis Island, of coral formation is 190 miles southwest of Christmas Island (at 0° 20' South latitude) and 1,100 miles east of Howland Island. It has an area of 2 square

JARVIS ISLAND

 $[\]overline{22}$ This figure was not reproduced.

 $^{^{23}}$ This figure was not reproduced.



miles. Jarvis has an airstrip and weather station. The island has no native inhabitants.

- (b) <u>Stage Fallout Range and Possible Downrange</u> <u>Tracking Sites</u> are about the same as for Christmas Island.
- (c) Excerpts from Previous Reports. "The size of this Pacific Island (2 square miles) is such as to severely limit future growth of a space base. The climate and range capability here are good. There is, however, little or no fresh water." -- Study on a Universal Launching Site for Space Missions, (Classified), Project Superb, ABMA, AOMC, Redstone Arsenal, Alabama, 30 January 1962, p. 4.

Also, according to "British to Back NASA Suggestion for Rocket Range Near Equator," <u>Space Age News</u>, 18 June 1962, p. 16, Jarvis Island has been surveyed by Hughes Aircraft Company as part of their <u>Syncom</u> Communications satellite project.

(18) PENRHYN (OR TONGAREVA) ISLAND

(a) <u>General</u>. Penrhyn Island, a coral atoll at 9° South latitude and 158° West longitude, comprises a circle of islets, and encircles a 108-square mile lagoon. The total land area is only 6.2 square miles. ²⁴ The lagoon may be entered through passages in the reefs, and on the west side of the lagoon, vessels of considerable size may enter. Copra and pearl shell are the chief exports.

Penrhyn Island is administered with the Cook Islands, a dependency of New Zealand, which is governed by a resident commissioner and a legislative assembly. The population in 1954 was 574.

(b) Stage Fallout Range

East: 500 miles to Caroline and Vortok Islands. 1,000 miles to Marquesas Islands, then clear to South America.

West: 700 miles to Tokelau and Phoenix Islands, then various groups are scattered all the way to Indonesia.

North: Several of the Line Islands within 1,500 miles. 2,000 miles to Hawaii.

South: 500 to 1,000 miles to the Cook Islands and fringes of the Society Islands, then

This value was obtained from <u>Selection of an Equatorial-Launch</u> <u>Site</u>, Technical Memorandum No. PMR-TM-60-13, Pacific Missile Range, Point Mugu, California, 28 December 1960. <u>Webster's Geographical Dictionary lists an area of 3 square miles</u>.



(c) Possible Downrange Tracking Sites (Eastward)

Caroline and Vortok Islands (about 10° South latitude): 500 miles.

Marquesas Islands (8° to 11° South latitude): 1,000 miles.

(19) FANNING ISLAND

(a) General. Fanning Island, at 4° North latitude and 159° West longitude, has an area of about 12 square miles. The population was 255 in 1940. Copra is the only export.

(b) Stage Fallout and Possible Downrange Tracking Sites are about the same as for Christmas Island.



(20) WASHINGTON ISLAND

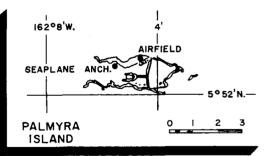
(a) General. Washington Island, at 4° 40' North latitude, has an area of 6 square miles, a length of 3.5 miles, and width of 1.2 miles. It is 70 miles from Fanning Island and 140 miles southeast of Palmyra Island. The population in 1942 consisted of 99 Gilbertese.

(b) Stage Fallout Range and Possible Downrange Tracking Sites are approximately the same as for Christmas Island.

(21) PALMYRA ISLAND AND KINGMAN REEF

(a) General. Palmyra Island is a partly raised atoll at 5° 52' North latitude, 33 miles southeast of Kingman Reef.

It is 1.5 square miles in area. Palmyra, and many islets around it, is surrounded by a coral reef. It has three lagoons. A naval air base was established on the island in 1939. Palmyra might well be considered U.S.-owned: "It was discovered in 1802 by the U.S.S. Palmyra, formally annexed by the U.S. in 1912, and was under the



jurisdiction of the city of Honolulu until 1959, when Hawaii became the 50th state of the U.S. The island is privately owned by the Fullard-Leo family of Hawaii, which employs some 30 persons to plant and harvest the coconut crop."²⁵

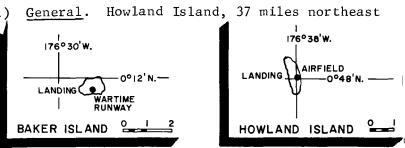
²⁵The Worldmark Encyclopedia of the Nations, New York, Harper & Brothers, 1960, P. 1097.



Kingman Reef, 6° North latitude is triangular, about 9 miles long with a base 5 miles wide, and it encloses a deep lagoon. It has been used as an experimental aviation school, but is now abandoned.

(22) HOWLAND ISLAND AND BAKER ISLAND

of Baker Island, is
1.5 miles long and
0.5 miles wide.
Its area is about 1
square mile, and
its latitude is 0°
48' north. An airfield was established



in 1937, and the island is an important stop between Australia and Hawaii.

Baker Island, an atoll at 0° 13' North latitude, has an area of 1 square mile.

(b) <u>Stage Fallout Range and Possible Downrange</u> <u>Tracking Sites</u> are approximately the same as for Christmas Island.

3. AMERICAN SAMOA

- a. Topography. American Samoa includes seven small islands of the Samoan Archipelago east of longitude $171^{\rm O}$ West. The islands are between latitudes $11^{\rm O}$ and $16^{\rm O}$ South, and their total area is 17.3 square miles. Five of the islands are volcanic, having rugged peaks, and two are coral atolls. Tutuila, by far the largest island of the group, is considered in more detail under Principal Islands.
- b. <u>History and Government</u>. The United States accepted sovereignty of the islands in 1929. First administered by the Department of the Navy, administration was transferred to the Department of the Interior in 1951.

The islands are administered by a governor, appointed by the Secretary of the Interior and approved by the President, and by various councils.

c. <u>Population and Culture</u>. In 1958, the population was estimated to be 21,960. Most of the inhabitants are Polynesian, and the economy is primarily agricultural.

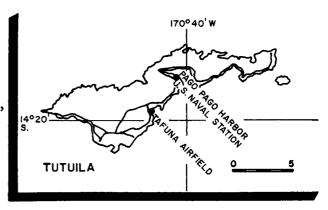
There were 5 doctors, 1 dentist, and 135 nurses and other medical personnel in 1958. The various schools had 288 teachers in 1959. Most of the inhabitants are Christian, but earlier beliefs are also followed.

- d. Climate. Temperatures range from $74^{\rm O}$ F in August to $90^{\rm O}$ F in December. Annual rainfall averages 190 inches, and the rainy season is from December through March. Hurricanes are common.
- e. <u>Transportation</u>. The capital island of Tutuila has the best natural harbor in the South Pacific. Airports exist, and are being improved. The islands had 80 miles of roads in 1959.
- f. Flora and Fauna. Wild animals are scarce. Ferns, coconut, hardwoods, and rubber trees flourish.
- g. Agriculture and Industry. Small farms occupy 31 per cent of the land, and various crops are cultivated. Swine and poultry are raised, but there are few cattle. Copra is the principal export. There is a modern tuna cannery. United States currency is the legal tender in the islands.

h. Principal Islands

(1) TUTUILA, the chief island of American Samoa, is

located at 14° South longitude and 170° 30' West longitude. Its area is 52 square miles, its length, 25 miles, and its width, between 2 and 6 miles. A mountain range runs the length of the island, having a high point of 2,141 feet above sea level. Tropical forest covers about 7 per cent of the island. The population of Tutuila is about 10,000, mostly Polynesians.



Pago Pago harbor is on the south coast at a deep indentation, and it has a U.S. naval station. Electric power and fresh water are available.

- i. <u>Stage Fallout Range from Tutuila</u>. There are numerous small islands around Tutuila in any direction except southeast.
- j. <u>Possible Downrange Tracking Sites (Eastward)</u> are numerous.
 - 4. TRUST TERRITORY OF THE PACIFIC ISLANDS AND GUAM.
- a. <u>Topography</u>. The Trust Territory of the Pacific Islands, administered by the United States, comprises 2,141 islands and atolls, of which only 98 are inhabited. Their total area is 687 square miles. The territory extends from 1° to 20° North latitude and from 130° to

172° East longitude. The Trust Territory includes three main groups of islands: the Caroline Islands, the Marshall Islands, and the Mariana Islands.

The Marianas and some of the Caroline Islands are of volcanic origin. The other islands are mainly coral atolls.

Topographical data concerning specific sites are set forth under Principal Islands of this section.

b. <u>History and Government</u>. Most of these islands were unknown until the nineteenth century. Japan occupied the islands in World War I. After withdrawing from the League of Nations in 1935, Japan fortified the islands. The United States took the islands one by one in World War II. In 1947, they became a United States Trust Territory. The islands are administered by the Secretary of the Interior and the Secretary of the Navy. Administration headquarters are on Guam (which is not included in the territory).

Guam, in 1950, became an unincorporated territory of the United States. It has a governor appointed every four years by the President of the United States.

c. <u>Population and Culture</u>. The population was 70,594 in 1958. The people speak several languages (for instance, nine Micronesian variations are spoken), and no one language is spoken territory-wide. United States currency is used.

Education is compulsory. The younger inhabitants are almost all literate. Christianity is the major religion, but there are numerous native beliefs.

d. Climate. The temperature varies in the district from 75° F to 85° F, with little seasonal change. Annual rainfall varies from 82 inches in the northern Marianas to 185.5 inches in the eastern Caroline Islands.

Typhoons occur from July to November, but they are not frequent in the eastern portion of the territory. The Guam area is subject to earthquakes.

Climatic data for specific sites are set forth in Principal Islands in this section.

- e. <u>Transportation</u>. Amphibious planes and surface ships travel from Guam to the district centers; these planes and ships are owned by the government and operated by a commercial firm. Airfields and docking facilities are listed in the Principal Island section.
- f. Flora and Fauna. Insects are numerous. The tropical bat is the only native mammal, although buffaloes, deer, goats, and

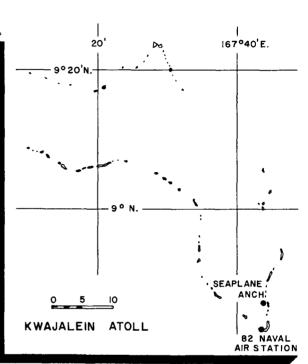
rats have been introduced. Fish are varied and abundant. Vegetation is fairly heavy. Coconut palms are abundant on the coral atolls, and hardwoods grow on the higher volcanic islands.

g. Agriculture and Industry. Only subsistence agriculture exists. The principal commercial products are copra and shell.

h. Principal Islands

(1) KWAJALEIN ATOLL

(a) General. Kwajalein Atoll, at 90 North latitude and in the west Marshall Islands, has a length of 78 miles and a width of 18 miles. Along with 80 sandy islets, Kwajalein forms a large lagoon, offering excellent anchorage. The southern portion is covered with dense coconut trees. Kwajalein was fortified by the Japanese in World War I. After the United States took the island in 1944, it became an American air and naval base. The population is approximately 1,100. Only a limited amount of fresh water is available.



(b) Stage Fallout Range

East: small islands in the Marshall group to 500 miles, then clear, except for Christmas and the northern Line Islands.

West: there is a complex of islands to the Philippines; however, a little to the south of these islands, there is a clear way from the equator to about 50 North latitude.

North: small islands in the Marshall group for 200 miles, 800 miles to Wake Island, then clear.

South: small islands in the Marshall group for 300 miles. 800 miles to Nauru, 1,200 miles to Santa Cruz Islands.

(c) Possible Downrange Tracking Sites (Eastward)

Several of the Marshall Islands within 300 miles. Howland and Baker Islands (1 North latitude): 1,300 miles.

Various of the Line Islands: about 2,500 miles.

(d) Excerpts from Previous Reports

"These islands²⁶ are also too small to allow for future growth and the equatorial range would cover the Line Islands."--Study on a Universal Launching Site for Space Missions, (Classified), Project Superb, ABMA, AOMC, Redstone Arsenal, Alabama, 30 January 1959, p. 3.

(2) PALAU (OR BABELTHUAP)

(a) General.

Palau is by far the largest island of the Palau group. It has a length of 27 miles and a width of 1 to 8 miles. Its area is 120 square miles. Palau is of volcanic origin, mountainous, fertile, and well-wooded. Volcanic craters on the west coast rise to an elevation of 641 feet. A series of both coral and volcanic islets extend for 30 miles to the southwest; these islets, from the northern tip of Palau, are surrounded by a barrier reef, forming a large lagoon. Palau's population is approximately 7,700. There is a surface water collection and reservoir storage system.

Malakal, one of the volcanic islands near Palau, is the chief port of the island group. There is a harbor 25 miles long and 5 miles wide, and a terminal capable of handling vessels up to 400 feet.

PALAU ISLANDS

O 5 10

BABELTHUAP

HARBOR

HARBOR

134° 20'E.

(b) Stage Fallout Range

The Marshall Islands, of which Kwajalein Atoll is typical, and "are also" refers to comments on the Gilbert Islands.

East: there are several island complexes due east,

but a little to the south is a clear way from the equator to about 50 North latitude.

West: 450 miles to the Philippines.

2,000 miles to Malaya.

North: 1,700 miles to Japan.

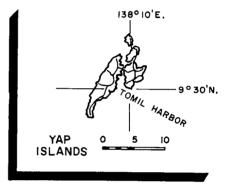
South: several islets within 300 miles. 700 miles to Netherlands New Guinea.

(c) Possible Downrange Tracking Sites (Eastward) are numerous, and most of them are at about 70 North latitude and at various longitudes.

(3) YAP

(a) General. Yap, in the western Carolines, is at 9° 35' North latitude and 138° 15' East longitude. It has a total

area of 38.7 square miles. The surface of the island is rugged and hilly (up to 585 feet above sea level). Yap actually comprises 4 islands close together, separated by long, narrow channels. There are dense forests of coconut palms, bamboo, and crotons. Yap is surrounded by a reef. One break in the reef allows anchorage on the southeastern side of the island, and there are several piers for small vessels. Tomil is the chief commercial harbor. In 1956 the population was 3,032 (only 20 per cent



of the 1900 population). About half the inhabitants are Roman Catholic; the other half, non-Christian. A rain water collection system provides the only fresh water available.

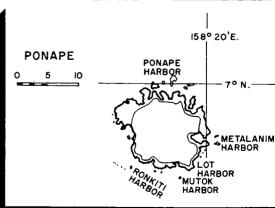
(b) Stage Fallout Range is roughly the same as for Palau.

(c) Possible Downrange Tracking Sites (Eastward)

are roughly the same as for Palau.

(4) PONAPE ISLAND

(a) General. Ponape (6° 55' North latitude and 158° 15' East longitude) has an area of 129 square miles. It is 12 miles long and 14.5 miles wide. It is surrounded by a reef, which also encloses 25 islets, and which forms a narrow lagoon. The interior is an irregular volcanic dome of black basaltic rock, bordered all around



by a rim of fertile coastal land. Some of the rivers have fertile valleys. Elevations range up to 2,600 feet above sea level. Settlements are along the coast, and the interior is sparsely populated. The population was estimated to be 5,735 in 1948. There is good anchorage, and the island has many fresh water streams.

(b) Stage Fallout Range.

East: 500 miles to Marshall Islands. 2,700 miles to Line Islands.

West: a complex of islands to the Philippines, but there is a clear way slightly to the south between the equator and 5° North latitude.

North: a few atolls within 400 miles, then clear

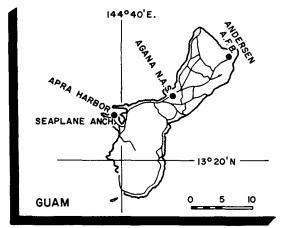
for 3,000 miles toward Siberia. South: several atolls within 400 miles 800 miles to Solomon Islands.

(c) <u>Possible Downrange Tracking Sites (Eastward)</u> are numerous and are at various longitudes and latitudes.

(5) GUAM

(a) <u>General</u>. Guam, the largest of the Mariana Islands, is an unincorporated territory of the Unites States. It has a latitude of 13° 26' North and a longitude of 144° 43' East. Its area

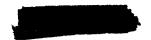
is 209 square miles, being 32 miles long and from 4 to 10 miles wide. The southern portion is hilly, with peaks to 1,334 feet above sea level. Fertile valleys in the south are watered by permanent streams. The northern half is mainly a plateau at about 500 feet above sea level. Much of the land is covered by dense jungle. A coral reef fringes much of the coast.



Apra Harbor, on the west coast, is the best anchorage.

There are 148 miles of paved roads. Guam is a regular stop for ships and airplanes. There were five military airfields during World War II. Fuel-burning plants generate electric power. A spring at Agana and wells supply fresh water. Limited housing is available.

Rainfall averages over 80 inches annually. The average temperature is 78° F. Guam is in the hurricane path. Storms are common during the summer months, and there are some typhoons. Earthquakes are frequent.



In 1959, the population was estimated to be 65,000. The majority of the Guamanians are Roman Catholics. There are several hospitals, and tropical diseases have been brought under control. In 1959, there were 22 schools and 1 junior college.

(b) Stage Fallout Range.

East: 1,200 miles to Eniwetok and Ujelang atolls.

1,500 miles to the Marshall Island complex.

4,000 miles to the Line Islands.

West: 1,250 miles to the Philippines.

North: numerous islets for 1,000 miles.

1,500 miles to Japan.

South: numerous atolls for 500 miles.

1,100 miles to New Guinea and Admiralty

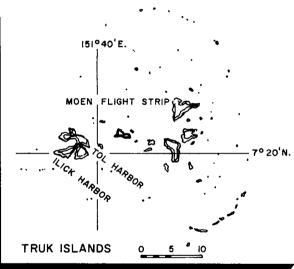
Islands.

(c) Possible Downrange Tracking Sites (Eastward) are numerous at various longitudes and from 5° to 7° North latitude.

Eniwetok and Ujelang atolls (about 12° North latitude): 1,200 miles.

(6) TRUK ISLANDS

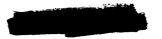
(a) General. Truk Islands, a group of 11 volcanic islands and many coral islets, form a triangular reef. They are located 925 miles east of Yap and 1,500 miles west of Tarawa, at about 7° North latitude. The total land area is 39 square miles. The two largest islands are Tol and Moen; Tol is 10 miles long and has a maximum width of 3 miles, and Moen is 5 miles long and 4 miles wide. High peaks reach 1,000 feet a-



bove sea level. In 1950, the population was 9,510; in 1938 it was 17,133 (estimate).

Four navigable passes give access to excellent anchorage in the lagoon area (about 140 square miles). The Japanese maintained a large naval base on Truk Islands during World War II.

(b) <u>Stage Fallout Range and Possible Downrange</u> Tracking Sites are approximately the same as for Ponape Island.



(c) Excerpts from Previous Reports

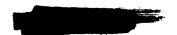
See the comments in the excerpt quoted under New Ireland in section 6.

5. SOLOMON ISLAND PROTECTORATE

- a. Topography. The Solomon Islands, a British Protectorate, lie between 5° and 12° South latitude and 155° and 170° East longitude. They are made up of a chain of fairly large islands and many islets, having a total area of 11,500 square miles. Elevations vary from the near sea level coral atolls to 8,000 feet above sea level at Guadalcanal. Many of the mountains and forests are inaccessible.
- b. <u>History and Government</u>. British protectorate in the general area was established in 1893, and various islands have since been added. The Solomons are one of several protectorates under supervision of the Western Pacific High Commission. Native representation is through an advisory council to the commissioner.
- c. <u>Population and Culture</u>. The population was 104,350 in 1955, including 98,000 Melanesians and 5,000 Polynesians; generally, the Melanesians inhabit the large islands, and the Polynesians inhabit the islets and atolls.

In 1957, there were four doctors, eight hospitals, and some dispensaries. There were 484 schools in 1958. Missions are active in educational activities. Christianity spread slowly in the Solomons, and it wrought great social change. English is the official language, but many other languages are spoken.

- d. Climate. Temperatures range from 72° F to 95° F. Annual rainfall averages 120 inches. The heaviest rainfall occurs from December through March. Humidity is high, and there is no well-defined dry season. Winds of gale force are rare.
- e. <u>Transportation</u>. Roads are few. There is a seaport at Honiara and the islands contain four airfields. Communication among the various islands is poor.
- f. <u>Flora and Fauna</u>. About 90 per cent of the island's area is covered by tropical forests. Vegetation is luxuriant. Palms grow on the coral islets. Fauna is sparse.
- g. Agriculture and Industry. Copra is the only important product, but gold and manganese exist in small quantities, and surveys indicate deposits of phosphate, copper, and asbestos.
 - h. Principal Islands.



(1) GUADALCANAL, 300 miles southeast of Bougainville at 9° 30' South latitude and 160° East longitude, has a length of 92 miles, a width of 33 miles, and an area of 2,509 square miles. The Kavo mountains traverse the island, reaching a high peak of 8,000 feet above sea level. Many short streams are along the coast. Most of the terrain is heavily wooded, and there are many coconut plantations. Some of the coastal regions contain mangrove swamps.

There are no really good harbors. Henderson Field, an airfield on the north coast, was built by the Japanese in 1942.

i. Stage Fallout Range.

East: several islands and islets within 100 miles, then

clear for 1,000 miles until reaching the Ellice and

other island groups.

West: numerous islands, New Guinea, and Indonesia compli-

cate the way to the Indian Ocean.

North: several islets within 500 miles, then clear to the

Caroline islands, 1,000 miles from Guadalcanal.

South: except for a few islets, the way is clear between

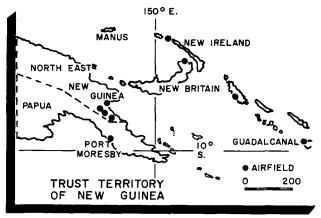
Australia and New Zealand to the Antarctica.

j. <u>Possible Downrange Tracking Sites (Eastward)</u> are numerous beyond 1,200 miles, and there are several within 500 miles.

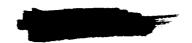
6. TRUST TERRITORY OF NEW GUINEA

The Trust Territory of New Guinea comprises northeast New Guinea, Manus Island, New Britain, New Ireland, and smaller islands. General

information is presented under several headings, then Manus Island, New Ireland, and Bougainville are considered in detail under Separate Islands. (New Britain, the territory of Papua, and Netherlands New Guinea are not considered here because a vehicle launched eastward would either travel over land or have a narrow flight path.)



a. <u>History and Government</u>. For 400 years the New Guinea area was annexed by various European nations. The Trust Territory of New Guinea, a protectorate of Germany in 1884, was taken by Australia in 1914. The Japanese occupied the area in 1942. In 1946, under the United Nations Trusteeship system, it was established that the territory would be governed by Australia. The Australian administer is



assisted by an executive council and a legislative council. The trend is toward establishing trained New Guineans in commissioned ranks and toward local government councils.

(The recent disputes between Netherlands New Guinea and Indonesia should not be associated with the Trust Territory of New Guinea.)

b. Population and Culture. The Trust Territory of New Guinea, according to a 1954 census, had a population of 1,195,307 natives, 8,020 Europeans, and 3,422 others. Christianity has been introduced, but most of the natives are of spirit and magic cults. Human sacrifices are sometimes made in ancestor cults, such as inhabit Manus Island.

In 1957, there were 229 schools operated by the administration and 4,013 mission schools. The languages vary widely. The administration is trying to establish English as a common language, and to prepare the natives for self-development.

- c. <u>Climate</u>. Annual rainfall varies from 45 to 245 inches. The monsoonal rainy season is from November to April, especially on the north coast of New Guinea; however, from May to October is the rainy season on the south coast of New Britain and New Ireland.
- d. Transportation. Cargo boats travel to New Guinea and the important islands in the territory. There are services to 100 government and 150 private airports. There are 5,548 miles of roads in the territory.

e. Principal Islands

(1) NEW IRELAND

- (a) <u>Topography</u>. New Ireland, at 3° South latitude, has an area of 3,340 square miles. It is nearly 200 miles long, and has an average width of about 10 miles. The island is very mountainous, but (unlike New Britain and New Guinea) it has no active volcanoes. The high point is 6,500 feet above sea level. There is a coastal fringe around most of the island; this belt contains coconut plantations. Most of the population lives in the northern portion of the island.
- (b) <u>Population</u>. The population in 1954 was 35,000, mostly natives.
- (c) <u>Transportation</u>. There are few good roads. Kavieng, at the north end, has a sea port.
- (d) Agriculture and Industry. Copra production is the major commercial activity.



(e) Stage Fallout Range.

East: about 1,200 miles to the south Gilbert

Islands .

West: congestion for 4,000 miles, across New

Guinea and Indonesia.

North: 600 miles to the Caroline Islands, then clear for 3,500 miles toward Japan.

(f) Possible Downrange Tracking Sites (Eastward)

Nauru (0° 31' South latitude): 1,000 miles. South Gilbert Islands (about 2° South latitude): 1,500 miles.

Various other sites out to 3,500 miles.

(g) Excerpts from Previous Reports.

"The next potential site is the southeastern tip of the large island of New Ireland in the Bismarck Archipelago, northeast of New Guinea and Australia. The geodetic coordinates are about latitude 4° 20' S., longitude 153° 15' E. Examination of Figure 10^{27} discloses that available exit azimuths relative to Stage I and II impacts are more numerous than for any other site yet considered.

"In the Stage I impact sector, many islands would complicate the choice of specific launch azimuths; however, launch azimuths from 0 to 180 degrees would be available for consideration. Additional study is necessary to determine the extent of the local restrictions imposed by the islands.

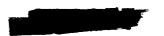
"Stage II water impacts would occur from the Arctic Ocean through the North and South Pacific to the Antarctic continent, except for a sector impinging on eastern Siberia and western Alaska from about 10 to 25 degrees where land impacts would be probable.

"If the launch site is moved westward to Manus Island (latitude 2° 4' S., longitude 147° E.), overflight of New Guinea and Australia begins to occur in the southerly sector, and no appreciable improvement in the Siberian-Alaskan situation is obtained.

"Mussau Island (latitude 1° 24' S., longitude 149° 38' E.) is an improvement over Manus in this respect, but immediate overflight of New Britain would occur.

"Truk Islands in the central Carolines at about latitude 7° 15'N., longitude 152° 12' E., offer approximately the same situation as New Ireland; there is some improvement in the southeastern sector but no improvement in the southern sector relative to New Britain Stage I impact.

²⁷ This figure was not reproduced.



"Westward launching from any of these sites would intensify safety problems in both impact sectors." -- Equatorial Launch Site Study, (Classified), Space Technology Laboratories, Inc., Los Angeles, California, 25 March 1960.

(2) MANUS ISLAND

- (a) <u>Topography</u>. Manus Island, located 200 miles to the north of New Guinea at 2° South latitude, is 50 miles long and 20 miles wide. Its area is 600 square miles. The central regions are densely mountainous, reaching 2,356 feet above sea level. The interior has not been fully explored. The eastern portion is fairly level and swampy along the coast. Manus Island is separated from the smaller Los Negros Islands by a narrow channel.
- (b) <u>Population and Culture</u>. The population was 13,217 in 1930. Water, power, and sewage disposal facilities are established.
- (c) Climate. The temperature is about 80° F in all seasons. Rainfall averages 150 inches a year, having no well-defined dry seasons. Rain usually occurs daily during late afternoons. Tropical cyclones are infrequent.
- (d) <u>Transportation</u>. Low coral reefs off the coast hinder navigation. The United States constructed an extensive naval base on Manus, dammed Lorengau River for hydroelectric power, and built a bridge to the neighbouring island of Los Negros (the site of Momote Airfield). After World War II, it was agreed that the United States and Australia would make use of the naval base facilities. A wharf, drydock, and refueling facilities have been built by the RAAF, and a 6,000 foot runway is available for aircraft. There are coralsurfaced roads traversing the island.
- (e) <u>Flora and Fauna</u>. Tropical forests cover the lowlands. Pine forests occur at altitudes of 2,000 feet above sea level, and there is limited vegetation in the hilly regions.

(f) Stage Fallout Range

East: 200 miles to St. Matthias islets.

1,300 miles to Nauru.

1,500 miles to Gilbert Islands.

West: New Guinea and Indonesia complicate the way

for 3,500 miles to the Indian Ocean.

North: 700 miles to the Caroline Islands.

South: New Guinea and Australia complicate the

way for 3,000 miles.

(g) <u>Possible Downrange Tracking Sites (Eastward)</u> are about the same as for New Ireland.



(h) Excerpts from Previous Reports

"The island appears suitable for both equatorial and polar missions, but there would be danger of booster fallout over inhabited islands. Manus Island would support a large population but here again the distance from the United States and the problem of logistics support seem to eliminate this location from further consideration in this report." -- Technical Considerations and Plans, (Classified), Project Horizon, Volume II, Department of the Army, 9 June 1959, p. 221.

Also, see the excerpt under New Ireland.

(3) BOUGAINVILLE

- (a) <u>Topography</u>. Bougainville, largest of the Solomon Islands, has a length of 125 miles, a width of 40 miles, and an area of 3,500 square miles. The island is traversed by a mountain range, in which there are two active volcanoes. The highest point is 10,171 feet above sea level. Much of the interior is unexplored.
- (b) Agriculture and Industry. The island has rich volcanic soil. There are many coconut plantations. Copra is the principal product, but coffee and cocoa are also exported.
- (c) <u>Transportation</u>. There are good harbors at Kieta, Buka, and Buin. Empress Augusta Bay offers good anchorage.
- (d) <u>Stage Fallout Range</u> values are about the same as those set forth for New Ireland.
- (e) <u>Possible Downrange Tracking Sites (Eastward)</u> are about the same as those set forth for New Ireland.

(4) MUSSAU ISLAND

- (a) <u>General</u>. Mussau Island, at about $1^{\rm O}$ South latitude and $149^{\rm O}$ East longitude, has a length of 20 miles and a width of 10 miles.
- (b) <u>Stage Fallout Range and Possible Downrange</u> <u>Tracking Sites</u> are approximately the same as for Manus Island, except that eastward launch clearance is improved.
- (c) Excerpts from Previous Reports. See the comments concerning Mussau in the excerpt quoted under New Ireland in this section.



7. THE REPUBLIC OF THE PHILIPPINES

- a. Topography. The Philippine archipelago comprises 7,100 islands situated from 4° 25' North latitude to 21° 25' North latitude, and from 118° East longitude to 127° East longitude. Most of the islands are mountainous. Other data are set forth under Principal Islands in this section.
- b. <u>History and Government</u>. Spain claimed the Philippine Islands in 1521. By 1572, the islands were made a province of New Spain, administered from Mexico. Rule was threatened by the Portuguese, the Dutch, the English, the Chinese, and by internal revolt. After the end of the Spanish American war, the Philippines came under United States rule. After continued Philippine rebellion, the United States Congress passed several bills, starting in 1902, to facilitate independence; but it was after World War II before the Republic of the Philippines was established.
- c. <u>Population and Culture</u>. The total population was estimated to be 24,718,000 in 1959. Nearly all the inhabitants are Malayan and Indonesian. English, Spanish, and Tagalog are the three principal languages. There are various religions, but 83 per cent of the people are Roman Catholics.

Nearly all the primary schools are operated by the government. There are several colleges, and the state-operated University of the Philippines had an enrollment of 17,000 in 1957. Sixty-five per cent of the inhabitants are literate.

- d. Climate. The average annual rainfall is 100 inches. Tropical storms and typhoons are frequent, especially in the northern islands. Other data are presented under Principal Islands in this section.
- e. <u>Transportation</u>. Water transport and air travel is well-established. The Philippines had 8,829 miles of national highways in 1958, and there were 695 miles of railway.
- f. Flora and Fauna. Reptiles are sparse, but include pythons, cobras, and crocodiles. Flora is varied and dense. Along the coasts and in river beds, mangrove swamps are common.
- g. Agriculture and Industry. About 22 per cent of the acreage is under cultivation, and about 45 per cent is under commercial forest. Rice and corn are the principal crops. The Philippines lead the world in copra production. Sugar and pineapples are also important.
- Gold, iron, and other minerals are important exports. Total electric power production was 1,114 million kwh in 1957. There is a large working force, and the number of unemployed people varies between 500,000 and 2,000,000, depending on the agricultural season.



h. Principal Islands

(1) MINDANAO, of irregular triangular shape, has an area of 36,500 square miles. It is the most equatorial of the Phillipine islands, its southernmost tip being about 50 North latitude. The coastline, 1,600 miles long, is indented with numerous bays. Mountains (up to 9,690 feet above sea level), high plains, and plateaus make up the interior, except for a few river valleys. The island has several active volcanoes.

Rain averages 100 inches annually, but the western side of the island is drier, averaging 43 inches annually. Mindanao is south of the typhoon belt common to the other Philippine islands.

i. Stage Fallout Range

East: there are many scattered islands due east; however, there is an eastward clearance from the equator to about 5° North latitude.

West: archipelagic complexes to the Indian Ocean, about 2,500 miles.

North: miscellaneous islands to the China mainland.

South: islands, Indonesia, and Australia complications for 3,000 miles.

j. Possible Downrange Tracking Sites are numerous.

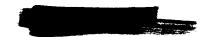
8. MISCELLANEOUS PACIFIC OCEAN SITES

a. <u>Netherlands New Guinea</u> sites were not considered in detail because a vehicle fired eastward would have to travel over or near the territory of New Guinea or the Bismarck Archipelago. It must be pointed out, however, that Waigeo Island, just off the northwest tip of Netherlands New Guinea, offers a very good eastward firing range, but the flight path would have to be within very narrow limits to avoid overflight of numerous islands.

b. Excerpts from Previous Reports

"WAIGEO (latitude 0° 15' S., longitude 130° 50' E.), off the northwest tip of Netherlands New Guinea, is within a half degree of the equator. For eastward launches, as shown in Figure 9, 28 it is apparent that for Stage II water impacts, this is the best site yet considered. In the sector of 0 degrees to about 30 degrees, there would be potential impact in areas around the Gulf of Anadyr and Chukotski Peninsula (Eastern Siberia), and western Alaska. However, from 30 degrees through 165 degrees, water impacts would occur in the North and South Pacific, except for possible land impacts on the outer

²⁸ This figure was not reproduced.



Aleutians and South Pacific islands in the vicinity of the Societies. From 165 to 180 degrees, Antarctica comes into the impact region.

"This favorable aspect changes very sharply, however, relative to Stage I impact sectors. The entire quadrant from 90 degrees through 180 degrees is severely restricted by the Bismarck Archipelago, New Guinea, and Australia. In general, except for local restrictions imposed by the islands, the quadrant from 0 to 90 degrees offers distinct advantages.

"Populated land areas in the southeastern quadrant plus possible Stage II impacts on the USSR in the north render this site impracticable.

"Palau and Yap, to the northeast, pose similar problems as launch sites. Guam offers some relief to these situations; however, Guam's latitude of about 13° North is reaching undesirable proportions.

"Westward launch from Waigeo is impractical since heavily populated Indonesia occupies a major portion of the potential Stage I impact area." -- Equatorial Launch Site Study, (Classified), Space Technology Laboratories, Inc., Los Angeles, California, 25 March 1960, p. 29.

c. HAWAII is not considered in detail in this report as an equatorial site. Ralph M. Parsons Company has prepared a report on Hawaii as a remote site, and an abstract of this report is set forth in section V. Also, NASA Study of Six to Twelve Million Pound Thrust Launch Vehicles, (Classified), North American Aviation Inc., Downey, California, 23 August 1961, states that the southeast end of the Hawaiian Islands is the most desirable launch site available for Novaclass vehicles because (1) the area is reasonably close to the equator, (2) there is no possibility of political difficulties, (3) local technical help is available, and (4) imported technical personnel would be willing to relocate in the area.

Hawaii is not considered in this report because of its distance from the equator. It is no more equatorial than Puerto Rico -- or Saudi Arabia -- or Madagascar -- or Australia -- and a study of all potential sites at latitudes as great as Hawaii would be lengthy.

d. INDONESIA is not considered in detail in this report because eastward launches would have to travel over congested areas for several hundred miles. Even if techniques are developed to recover boosters safely, Indonesia would present problems: the terrain is the most volcanic region on earth.

e. GALAPAGOS ISLANDS

(1) <u>Topography</u>. The Galapagos Islands, an archipelago consisting of 12 islands and several hundred islets, lies astride the

equator 700 miles from the coast of Ecuador at 90° West longitude. These islands have a total land area of about 3,000 square miles. Over half of this area is covered by Isabela, the largest island of the group (over 75 miles long). Isabela has a slightly active volcano reaching 5,540 feet above sea level, and four smaller inactive volcanoes. Other islands have mountains up to 3,000 feet above sea level. The coast of most of the islands is composed of alternating dense mangroves, white sand beaches, and rugged lava cliffs. Most of the islands, formed by subterranean volcanic action, are circular with a single crater in the center. Because of the porosity of the volcanic soil, rainwater quickly drains, and there are few permanent streams on the islands.

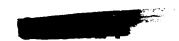
(2) <u>History and Government</u>. The Galapagos Islands stood barren for centuries. They were a pirate haven in the seventeenth century, and in the nineteenth century they became a victualing center for whaling ships.

Ecuador made the Galapagos a territory in 1832. The islands, being close to the Panama Canal, were of strategic importance in World War II, and an air base was constructed on Seymour Island in 1941. The base was turned over to Ecuador in 1946: "A preliminary agreement was reported to have been made in September 1945 for permanent U.S. air and naval bases in the islands in return for a U.S. Export-Import bank loan but popular opposition prevented its consummation."²⁹

In 1936 Ecuador made a national park of the Galapagos. No exploration is allowed without Government permission. Tourist trade is expected to increase.

- (3) <u>Population and Culture</u>. Only four of the islands were inhabited in 1950, and the total population was 1,346. Many settlements have been attempted without success.
- (4) <u>Climate</u>. The cold Humboldt Current produces a mild climate with a mean temperature of 70° F. Desert-like low-lying areas have little rain as compared to elevations above 800 feet. From January to April is the rainy season; annual average is 48 inches.
- (5) <u>Transportation</u> is probably undeveloped on the islands. No specific information was found, except that there was an airfield as late as 1946.
- (6) Flora and Fauna. The Galapagos are noted for rare species of flora and fauna; it has been a mecca for scientists since the time of Charles Darwin. Above 800 feet, there are dense jungles of trees and ferns; at lower altitudes, flora is relatively sparse. Unlike most equatorial regions, there are no palm trees on

²⁹ Encyclopedia Britannica, 1960, p. 968.



the Galapagos. The islands have giant tortoises; some are over 400 years old and weigh 500 pounds. Giant species of lizards (up to 4 feet long) are found, but there are no poisonous snakes. There are 85 species of birds. Because of the abundance of plankton in the surrounding water, the Galapagos is a rich fishing area.

(7) Agriculture and Industry. Fishing is the principal occupation. Several attempts at colonized farming failed. The low arid parts of the islands have little soil, and it is quickly exhausted. Small quantities of cane, coffee, and vegetables are cultivated.

(8) Stage Fallout Range (Eastward):

East: 700 miles to the west coast of South America. West: 4.500 miles to the Line Islands in the Pacific.

North: 900 miles to Central America.

South: 5,000 miles to Antarctic (except for a few islands southeast, off the coast of Chile.)

(9) Possible Downrange Tracking Sites

Ecuador: 700 miles. Other tracking sites would be possible in the interior of South America.

E. OTHER LAUNCH SITE CONCEPTS

Studies have been made of self-propelled, barge-type, floating drydock, and Texas-tower off-shore launch sites. Some advantages and disadvantages of these concepts are as follows:

1. Off-Shore Launch Pads

Advantages:

- (a) Maximum use can be made of land-based capabilities, ground support equipment, safety provisions, and present facility designs.
- (b) The launch pad can be connected to the mainland by pier, causeway, or extension of land mass.
- (c) Increased launch rates can be maintained, as necessary, by additional construction.
- (d) Standard launching procedures can be used.

III-60

(e) Logistics support cost is reduced, as compared to drydock or ship launching concepts.

Disadvantages:

(a) Increased cost because of construction problems.

2. Mobile Self-Propelled Launch Concept

Advantages:

- (a) Optimum launch point can be selected.
- (b) Covert launch is possible.
- (c) Existing range instrumentation could be used.
- (d) A ship-type launch facility could adapt to unusual launch requirements.
- (e) Vehicles could be checked at factory.
- (f) Construction and possible modification could be accomplished stateside.

Disadvantages:

- (a) Limited space.
- (b) New "ground support" equipment would be required.
- (c) Safety hazards.
- (d) Development time. A launch ship would require much research and development to perfect launch techniques for Saturn-class vehicles.

3. Barge or Drydock Launch Concept

- (a) Optimum launch point can be selected.
- (b) Existing range instrumentation could be used.
- (c) Economy
 - (1) Existing hulls can be modified.
 - (2) All but the smallest drydock units contain power generators, large gantry cranes, ships, and personnel quarters.

(d) Flexibility

(1) Units are semi-mobile and can be relocated.

- (2) Units can be modified to handle larger units.
- (3) Drydocks can accommodate liquid, solid, or nuclear propelled vehicles.
- (4) Combinations of land and drydock units could be used.

(e) Safety

- (1) A drydock unit can avoid populated areas.
- (2) A drydock unit could jettison the vehicle.

Disadvantages:

- (a) The drydock would require support from other vessels or land sites, especially for remote operations.
- (b) Long delays in operation would ensue from any major casualty.

Combinations of drydock, islands, and off-shore launch pads are conceivable. In some cases, two or more neighboring islands (possibly connected by a railed pier) might be useful.

Italy is planning to launch vehicles from a floating platform which can be towed to equatorial waters, and it is proposed to use a second floating base as a command center. 30

Off-shore launch facilities have been proposed to expand the Cape Canaveral launch complex. One concept is to extend a pier from the shore facilities to an off-shore launch pad and docking area. This arrangement, besides extending the effective area, facilitates unloading a vehicle from a barge or ship (by cranes atop the service tower) directly onto the service pad. A similar concept might work nicely in the still waters of an atoll's lagoon.

Some otherwise desirable atolls have neither good docking facilities nor anchorages, and many of them are considered by some reports to be too small for a launch site. A pier-type off-shore launch complex could help alleviate these faults. A pier could extend from the lagoon, over the land area, and beyond the fringing reef to a ship berthing area. Properly annexed launch pads in the lagoon, connected by rail to the main pier, could facilitate vehicle handling. One concept is to have off-shore launch pads within a lagoon, to unload the

^{30 &}quot;British to Back NASA Suggestions for Rocket Range Near Equator," Space Age News, 18 June 1962, p. 16.

vehicles from a ship at the anchorage or dock, to transport the vehicle by barge to the launch site, and then load it onto the launch pad. A pier-type facility would simplify this operation; a pier would allow a service tower to take the vehicle directly from a ship and transport it by rail to the launch pad, plus serving as a supply conduit for utilities from the on-shore facilities.

TABLE III-1: COMPARATIVE SITE DATA

											L	L		MILES TO U.S. PORT
Amazon Basin	o°	49° W	Brazil	Brazil 3,287,842	Sea Level to 9,462	Brazil 51,944,397	86	78°F	Yes	Not at	Not at	Not at	Not at	2,900
French Guiana	50 to 70 N	52° W	France	34,740	3,000	27,863	130	88°F	Yes	Yes	Yes	Yes	Yes	2,375
British Guiana	6° N	56° W	U. K.	83,000	9,219	507,000	75	88°F	Yes		Yes	Yes	Yes	2,100
Ascension	8° S	15° W	U. K.	38	2,817_	173	20		Yes	Yes	Yes	Yes		5,200
St. Helena	16° S 12° N to	5° W	U. K	47	2,685	5,000	40		Yes		Yes		Yes	6,000
Somalia	10 S 50 N to	45° E	Somalia .	195,000	8,250	1,330,000	40 to	80°F	Uncertain	Yes	Yes	Yes	Yes	10,639
Kenya	5° S	37° E	Kenya	224,960	17,040	6,351,000	100 90 to	80°F 68°F to	Yes	Yes	Yes	Yes	Yes	8,200
Seychelles	4° s	56° €	U. K.	156	2,993	34,632	150	880F	Yes	No	Yes	Yes	Yes	9,100
Maldive	70 N to 10 S	73° £	Maldive Republic	115	20	90,000		81°F	Yes	Yes	Yes	Yes	Yes	9,400
Chagos Archipelago	6° S	72 ⁶ E	U. K.	76		1,048				Yes.				10,500
Nuku Hiva	9° S	140° W	France	130	3,888	550	30 to 100	78°F	Limited	No	Yes		No_	3,250
Ua Pu	9° s	140° W	France	40	4,040	380	30 to 100	78°F	Limited	No	Yes		No	3,250
Ua Huka	9° S	140° W	France	30	2,805	150	30 to 100	78°F	Limited	No	Yes		No	3,250
Tahuata	10° S	140° W	France	20	2,000	250	30 to 100	78 ⁰ F	Limited	No	Yes		No	3,250
Fatu Hiva	11° S	140° W	France	25	3,670	200	30 to 100	78 ⁰ F	Limited	No	Yes		No	3,250
Eiao	8° S 9° S	140° W	France	20	2,000	Q.	30 to 100	78°F	Limited	No.	Yes		No	3,250
Hatutu	9 ⁶ S	140° W	France		1,380	0	30 to 100	78°F	Limited	No	Yes	200	No	3,250
Mohotani	9° §	140° W	France	6	1,700	Ó	30 to 100	78°F	Limited	No	Yes		No	3,250
Hiva Oa	10° S	140° W	France	125	4,134	850	30 to 100	78°F	Limited	No	Yes		No	3,250
Tarawa	1° N	173° E	U. K.	7.7	Near Sea Level	3,582	75	81°F	Rainwater only	Yes	Yes	Yes	No	4,875
Tabiteuea	1° s	175° E	U. K.	19	Near Sea Level	3,856	50	81°F	Rainwater	No	112		No	4,950
Beru	1° s	176° E	U. K.	8.2	Near Sea Level	2,468	50	81°F	Rainwater only	No.			No.	4,875
Arorae	3° s	177° E	U. K.	5	Near Sea Level	1,550	50	81°F	Rainwater	No.	t			
Nukunau	1° 5	177° E		,	Near			81°F	Rainwater				No	4,900
	2° N		U. K.		Sea Level Near	1,592	50		only Rainwater	No			_No	4,850
Kuria		173° E	U. K.	4.5	Sea Level Near	300	50	81°F	only Rainwater	No			No.	4,875
Aranuka	2° N	173° E	U.K.	6	Sea Level Near	366	50	81°F	only Rainwater	No			No	4,875
Onotoa	2° S	176° E	U.K.	5.2	Sea Level	1,490	50	81°F	only	No			No	4,900
Ocean	1° s	170° E	U. K.	2	265	2,060		80°F		No	Yes		Yes	5,300
Nauru	lo s	167° E	Australia	8.2	225	4,308		80°F		Yes	Yes		Yes	5,400
Nonouti	1° S	174° E	U. K.	9.9	Near Sea Level	2,084	43	81°F	Rainwater only	No	Yes	No	No	4,850
Abemama	00	174° E	U. K.	6.6	Near Sea Level	841	50	81°F	Rainwater only	No	Yes	No	No	4,875
Canton	3º S	172° W	U.S./U.K.	4	Near Sea Level	340	19	84°F	Rainwater only	Yes	Yes		Yes	4,300
Malden	4° s	155° ₩	v.s./v.k.	35	Near Sea Level	0	27	84°F	Rainwater	No	No	No	No.	3,575
Starbuck	6° s	156° W	U.S./U.K.	8.1	Near Sea Level	0	27	84°F	Rainwater	No	No	No	No.	
Christmas	2° N	157° W			40		27	74°F to						3,700
Jarvis Island	00 N	160° W	U.S./U.K. U.S./U.K.	160 2	22	52	22	91°F 82°F	Limited No	Yes Yes	Yes	Yes	Yes	3,300
Penrhyn	9° s	158° W	New Zealand	6.2	Near	574	50	90° F Max			NO	No	No	3,610
	4° N	159° w	U. K.	12	Sea Level		30	90 F MAS		Yes		-	No	
Fanning	1				Sea Level Near	255				No	Yes	 	Yes	3,375
Washington	5° N	161° W	U.K. U.S.	6	Sea Level Near	99	-		Yes					3,300
Palmyra	6° N	162° w	Private	1.5	Sea Level	32				Yes	-			3,375
Howland	1° N	176° W	U.S./U.K.	1	Sea Level			74°F to	Limited	Yes	Yes			4,300
Tutuila	14° s	171° W	U.S.	52 Land Area	2,141 Near	10,000	100 to 190	90°F	Yes	Yes	Yes	Yes	Yes	4,810
Kwajalein	9° N	168° E	U.S.T.T.	Uncertain	Sea Level	1,100	100	81°F	Limited Rainwater	Yes	Yes	Yes	Yes	4,900
Palau	8° N	135° E	u.s.r.r.	120	641	7,700	100	80°F	only Rainwater	Yes	Yes	Yes	Yes	6,800
Yap Ponape	10° N	138° E	U.S.T.T. U.S.T.T.	38.7 129	585 2,600	3,032 5,735	115	80°F	only	Yes	Yes	Yes Yes	Yes	6,500 5,500
Guam	13° N	145° E	U. S.	209	1,334	65,000	80	78°F	Yes	Yes	Yes	Yes	Yes	6,000
Truk	70 N	152° E	U.S.T.T.	39	1,000	9,510	89	81°F 72° F to	Limited	Yes	Yes		Yes	5,825
Guadalcanal New Ireland	9° s	160° E	U. K. Australia	2,509 3,340	8,000 6,500	33,000	120	95 ⁶ F	Yes	Yes Yes	Yes	Yes	Yes Few	6,000
Manus	2° s	147º E	Australia	1,000	2,356	13,217	150	80°F	Yes	Yes	Yes	Yes	No	6,550
Bougainville	60 S 50 N to	155° E	Australia	3,500	10,171	40,000	130	80°F	Yes	Ies	Yes	Ies	No	6,000
) by N to	1230 E to		1	1	1	Į.	l .	1		1	1	1	7.300
Mindanao Hawaii	9° N 19° N	126° E	Philippines U. S.	36,500 4,030	9,690 13,785	2,450,000 61,332	100	82°F 79°F	Yes Yes	Yes Yes	Yes Yes	Yes	Yes Yes	2,425

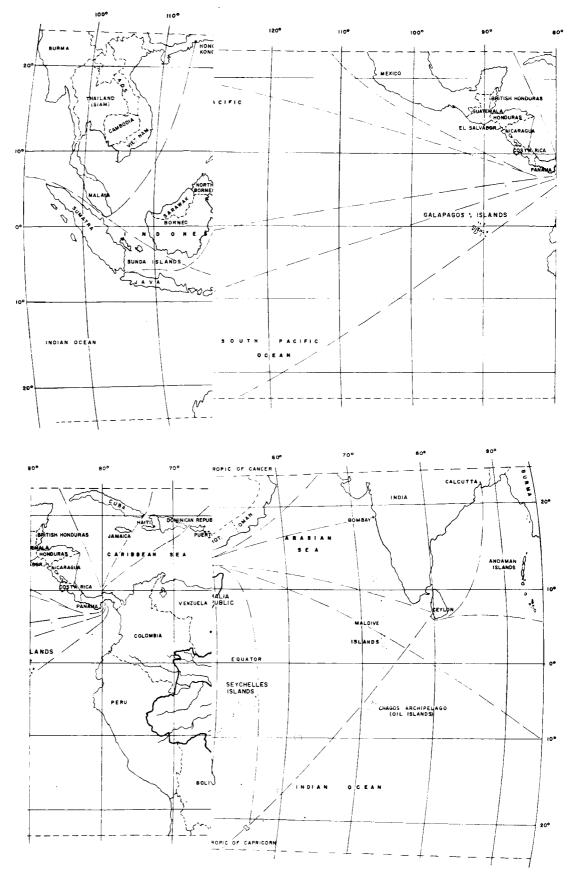


FIG. III-1: POTENTIAL EQUATORIAL LAUNCH SITES

IV. ABSTRACTS OF SELECTED EARLIER REPORTS



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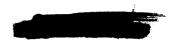


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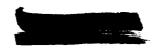


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A. The Effect of the Earth's Oblateness on the Orbit of a Near Satellite, TECHNICAL NOTE G.W. 475, Royal Aircraft Establishment, London, England, October 1957

This study presents, through a perturbation method, approximate analytical solutions for the equations of motion of a satellite in orbit over an oblate earth in vacuo.

The solutions apply primarily to orbits for which the maximum and minimum altitudes of the satellite do not differ by more than 300 nautical miles.

It is concluded that the earth's oblateness has four main effects on the motion, as computed for a mean orbital altitude of 200 nautical miles:

- 1. The orbital plane, instead of remaining fixed in direction, rotates about the earth's axis in the opposite sense to the satellite, at a rate of about 8 $\cos\alpha$ degrees per day, where α is the inclination of the orbital plane to the equatorial plane.
- 2. The period of revolution of the satellite, from the northward crossing of the equator to the next, is about 14 $\sin^2\alpha$ seconds greater for an inclined orbit than for an equatorial orbit.
- 3. The radial distance r from the earth's center changes; for a given angular momentum, the mean r is some 13 n.m. greater for a polar orbit than for an equatorial one. Also, during each revolution r oscillates twice, the amplitude of the oscillation being 0.9 $\sin^2 \alpha$ n.m. under the simplest initial conditions.
- 4. The major axis of the orbit rotates in the orbital plane at a rate of about 4 (5 $\cos^2 \alpha$ 1) degrees per day. Thus it rotates in the same direction as the satellite if $\alpha < 63.4^{\circ}$, or in the opposite direction if $\alpha > 63.4^{\circ}$.
- B. Study on a Universal Launching Site for Space Missions (Classified), (Project Superb), ABMA, AOMC, Redstone Arsenal, Alabama, 30 January 1959

This study endeavors to examine possible launching sites to determine which single location would best meet the requirements of the many types of space missions contemplated for the future.



The study explains that a satisfactory space vehicle launching site should permit rendezvous with orbiting bodies without undue complexity, utilization of earth's rotational energy to as great a degree as possible, simplicity of guidance for lunar and planetary probes, and entry into desired trajectories with as little energy penalty as possible. Factors such as logistic support, safety, climate, and growth potential must also be considered.

It is explained that many space projects now being considered will require support from shuttle rockets. The provision of such support will be greatly simplified if the orbiting station is made to pass over the launching site with each revolution.

In addition to the regularity of advantageous passes there are other rendezvous factors which are simplified by the coplanar relationship of firing site and orbit, as requirements of guidance, timing, and propulsion would be lessened considerably.

It is claimed that for interplanetary flights the launching site should be within 23 degrees of the equator, and within 18 degrees for lunar missions.

The need is outlined for a single equatorial site which would serve as both the R & D anti-satellite base and the launch point for the "target" satellites in anti-satellite system research.

It is pointed out that preliminary information on the belts of radiation surrounding the earth (based on Explorer and Pioneer III data) indicates that manned orbital activity near the equator will be practical, but may be limited to fairly low altitudes in the order of 500-600 miles. Although some amount of shielding will be necessary, it is considered feasible for man to pass through these radiation belts (for lunar or planetary flights) if the period of exposure is short. The weight. penalty in shielding is considered to be less than the penalty for firing from the polar regions to avoid the radiation belts.

A chart outlines the factor by which launch weight is increased with orbital plane change needs.

A survey of possible sites in the study indicates that the following sites are favorably located and allow some flexibility in allowable firing azimuths: (1) Gilbert Islands, (2) Marshall Islands, (3) British Guiana, (4) Mouth of the Amazon, (5) Somalia, (6) Jarvis Island, and (7) Christmas Island.

A large number of other possible locations were considered and eliminated on the basis of obvious inadequacies in size and range safety. In addition to the above, there exists the possibility of launching from an artificial site such as a ship or man-made island. Neither of these possibilities would allow the desired flexibility and growth potential without prohibitive cost.

The first six of these locations are rejected from the study with the following major objections to their use:

Gilbert Islands--size not considered adequate, and equatorial firing range would cover inhabited Line Islands.

Marshall Islands--too small for future growth, and equatorial firing range would cover inhabited Line Islands.

British Guiana--too far from equator, and unfavorable political situation.

Mouth of the Amazon, Brazil--unfavorable political situation, and extremely hot and humid climate.

Somalia--location too remote from continental U.S.

Jarvis Island -- too small for future growth.

Christmas Island is discussed at length. It is described as being at $2^{\rm O}$ latitude, with approximately 200 square miles of land area. It is listed as being under joint U.S.-British control, with pleasant climate, few inhabitants, and harbor and air terminal facilities.

A detailed map is provided, and proposed facilities are indicated and discussed.

It is concluded that Christmas Island is the most acceptable universal site available, and it is recommended that action be initiated to establish a launching base at this location.

C. <u>Hawaiian Launching Base</u>, ENGINEERING FILE NO. 606-1965, Ralph M. Parsons Co., Los Angeles, Calif., March 1959

The purpose of this study is to establish functional requirements of a launching base and support complex in the Territory (now State) of Hawaii for the express purpose of launching space vehicles into polar orbit.

The Island of Hawaii is chosen as a site after having been considered from the standpoint of the following geotechnical features:



(1) political status, (2) location, (3) topography, (4) climate, (5) flora, (6) development, and (7) functional assets. Projected technical facilities, conventional facilities, and site preparation (including utilities) are outlined and mapped.

Estimated costs are outlined in table form in three increments of construction.

A proposed project schedule extending 72 months is presented.

The report was completed more to determine feasibility than to establish conclusions, but it is indicated that the proposed launch site on the Island of Hawaii would be satisfactory to meet the needs of the United States for the launching of satellites and space vehicles into polar orbit.

D. Planning Guide--Equatorial Orbit Launching Site, ENGINEERING FILE NO. 606-1953, Ralph M. Parsons Co., Los Angeles, Calif., March 1959

The specific aims of this study are to describe potential sites, present the nature and scope of facilities to be developed, show a typical development for an equatorial orbit launching base, estimate the cost of construction, and indicate the phases of implementation and time required to make a typical site operational.

The study includes data on the following possible sites: Palau Island, Yap Islands, Tarawa Atoll, Guam, Kwajalein Atoll, Manus Island, Ponape, Christmas Island, and Tutuila in Eastern Samoa. Each is considered as to location, political status, land area, topography, vegetation, water supply, harbor, industrial development, and population.

Maps pinpoint and lay out the general configuration of each possible site.

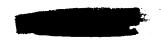
A general project concept outlines technical facilities, support facilities, community facilities, and utility and transportation systems needed. A general development plan schedule and table of construction costs are included.

No conclusions are drawn.

E. <u>Development Plan--Manus Island Pacific Missile Range</u>, ENGINEERING FILE NO. 606-1966, Ralph M. Parsons Co., Los Angeles, Calif., March 1959

This is a study of the potential development of a launching base, a tracking facility, and a communications center on Manus Island, two degrees south of the equator at Longitude 147 degrees east.





The study includes projected plans for a launching base, tracking station, communications center, administration area, maintenance facilities, supply facilities, community needs, utilities, and transportation facilities.

Detailed maps accompany the plans. A table of estimated development costs and a development plan schedule are included.

The study concludes that Manus Island, from a cursory analysis, appears suitable for development to support the operations envisioned and to provide the minimum area considered necessary.

F. <u>Saturn System Study</u> (Classified), U. S. Army Ordnance Missile Command, Redstone Arsenal, Alabama, 13 March 1959

This report summarizes the results obtained in a system study by the Future Projects Design Branch of the U. S. Army Ordnance Missile Command for the determination of the best combination of stages for the Saturn space flight vehicle.

Fourteen of the most promising configurations were selected for further study out of 1,375 which were screened. The 14 vehicle configurations represent basically four families: (1) Atlas family, (2) Titan family, (3) Centaur family, and (4) the $0_2/\mathrm{H}_2$ family.

It is assumed that there will be 100 flights during the period 1960 through 1964, including 20 lunar or deep-space flights, 20 high-altitude or the 24-hour orbit class, and 60 low-altitude orbital flights.

The question of launch site location is considered a very important parameter in determining the net worth of the Saturn program. It is anticipated that approximately 60 per cent of the Saturn flights will be low-orbit, and that the majority of these flights will require an equatorial orbit for such missions as establishment of small, medium, and large space stations, orbital supply flights, and orbital transportation of materials for assembly of deep-space vehicles which will depart from orbit.

It is expected that these and many other flights will require large payloads which will be available only if the Saturn is launched from an equatorial site.

It is estimated that the payload capability of a typical Saturn vehicle which doglegs into an equatorial 300-nautical-mile orbit from AMR is approximately 70 per cent less than for one which is launched due east from an equatorial launch site.



The following figures are designated as typical of payload loss through the utilization of a non-equatorial launch site:

Vehicle Configuration	Launch Site	Payload Capabilities in lbs for Designated Missions Equatorial Equatorial				
		96-min Orbit	24-hr Orbit			
Saturn Booster plus	Equatoria1	30,900	6,200			
Atlas plus Centaur	AMR	8,800	5,000			
Saturn Booster plus	Equatorial	30,850	5,300			
Titan I plus Centaur	AMR -	8,700	4,250			

It is estimated that a typical equatorial site Saturn vehicle 100-flight program, 1960 through 1964, should require \$165,000,000 more than for the same program at AMR. But the total payload delivered into space from the equator would be approximately 1,000,000 lbs, or 240 per cent more than the same program using AMR. In terms of cost, the average cost per 1b at AMR would be approximately \$1,700, as compared to only \$790 per 1b from an equatorial launch site.

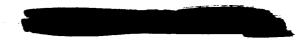
It is emphasized that the rendezvous problems for a nonequatorial orbit are much greater than for an equatorial orbit, as opportunities to launch directly into the non-equatorial orbital plane are often separated by weeks for the non-equatorial launch site as compared to hours at most for the equatorial plane.

Subsequent launching from a space platform within the ecliptic is also described as being simplified if the equatorial orbit is used, as it is the most stable orbit available.

Further advantages outlined include the fact that launchings from the equator take full advantage of the earth's rotational velocity of over 1,500 feet per second. The frequent overhead passage of the equatorially orbiting vehicle permits better tracking and communications, and earth-launched attempts for other missions within the solar system are also simplified by utilizing an equatorial launch facility.

The establishment of an equatorial orbit from AMR is described as being hampered through requiring a more complex guidance system which both adds weight to and reduces the reliability of the vehicle. Velocity losses of as great as 13,000 feet per second for low orbits may be incurred through necessary correction of pitch angle, waiting orbit loss, and orbital plane transfer for equatorial orbit launchings from AMR.





It is concluded:

- 1. An equatorial launch site would provide the capability of transporting 1,000,000 lbs of payload approximately one year earlier than AMR.
- 2. An equatorial launch site would provide the capability of transporting 1,000,000 lbs of payload for \$586,000,000 less than AMR.

(A major portion of the Saturn System Study has been omitted from this abstract as being inapplicable to the present study.)

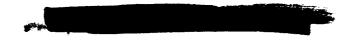
G. Payload Loss for Equatorial Orbits Due to Non-Equatorial Launches, PMR-MP-59-13, Pacific Missile Range, Point Mugu, Calif., 2 April 1959

This is a study of payload losses incurred through the use of various hypothetical non-equatorial launches to attain equatorial plane orbits as compared to hypothetical equatorial launches to attain the same orbits.

Calculations in the study are based upon latitude of the launch site and these five key parameters: fuel specific impulse, rocket structural factor, altitude of desired orbit, range of preliminary rocket trajectory, and ratio of the apogee and circular orbit velocities.

Three model non-equatorial launchings are explored:

- 1. A launching at latitude λ from which a final stage is put into a path with apogee at the plane of the equator and at the altitude of a desired circular equatorial plane orbit.
- 2. A launching at latitude λ in which the assumed procedure is to launch due east, using part of the fuel in the final stage of apogee to kick the remainder of the final stage into circular orbit of the desired altitude, then to use the remainder of the fuel to turn the vehicle into a true equatorial orbit as it passes into the equatorial plane.
- 3. A launching at latitude λ by firing due east into a circular orbit, followed by a transfer to an elliptical orbit with an apogee equal to the altitude of the stationary orbit (22,300 statute miles above the earth), with a final impulsion to place the payload into circular equatorial orbit as the apogee crosses the equatorial plane.



Basic formulae for all computations are included, with explanation that the figures are only rough estimates. Model non-equatorial launchings are charted for 300-mile-high and 22,300-mile-high circular equatorial orbits.

Graphs are provided to demonstrate:

- 1. Percentage of payload loss for non-equatorially launched 300-mile-high equatorial orbits from varying latitudes for both circular orbit and apogee transfer. Parameters are: downrange to apogee, 1,000 miles; apogee and circular orbit velocity ratios, 0.543 and 0.8; specific impulse, 290 seconds; and structural factor, 0.25. Payload loss rises to 100 per cent at slightly beyond 3 degrees latitude with circular orbit transfer and to 100 per cent at slightly beyond 7 degrees latitude with apogee transfer.
- 2. Percentage of payload loss for non-equatorially launched 300-mile-high equatorial orbits at varying latitudes for both circular orbit and apogee transfer. Parameters are: downrange to apogee, 3,000 miles; apogee and circular orbit velocity ratio, 0.528, specific impulse, 400 seconds; structural factor, 0.33. Payload loss rises to 100 per cent at around 24 degrees latitude with both apogee and circular orbit transfer.
- 3. Percentage of payload loss for non-equatorially launched stationary satellites or 22,300-mile-high equatorial orbits at varying latitudes. Parameters are: apogee and circular orbit ratio, 0.528; specific impulse, 400 seconds; and structural factor, 0.33. Payload loss rises to about 24 per cent at 34 degrees latitude.

Conclusions:

- 1. The only positive statement that can be made about the payload loss associated with the latitude of the launch site is that the loss increases as the latitude increases.
- 2. The payload loss decreases as the downrange distance to apogee increases.
- 3. The payload loss decreases as the specific impulse of the fuel increases.
- 4. The loss in payload is very sensitive to structural factor when it is relatively large, when the altitude is low, and when the specific impulse is moderate.
- 5. The apogee velocity has considerable effect on loss in payload when low altitudes are accompanied by moderate specific impulses and large structural factors.

- 6. Whether a launch site at a particular latitude is satisfactory or unsatisfactory relative to payload loss depends entirely upon the parameters chosen in analysis of the loss and upon what size penalty is deemed unsatisfactory.
- H. A U. S. Army Study for the Establishment of a Lunar Outpost (Classified), Project Horizons Report, TECHNICAL CONSIDERATION AND PLANS (U), Volume II, 9 June 1959

This is the second of two volumes of a preliminary feasibility study for the establishment of a lunar outpost by 1966. It deals with the technical requirements and indicates the way and means for the actual accomplishment of this mission. It does not discuss other missions which the Saturn vehicles (around which the program is built) are expected to accomplish.

The study discusses the earth-lunar transportation system from the vehicle design, transportation system integration, and economic points of view. It also includes the earth support operation, with earth-launching and servicing facilities, as well as the complete earth-lunar communication system.

Assumptions include:

- 1. The objective is limited to the establishment and support of a 12-man outpost, although exploitation possibilities are discussed.
- 2. The lunar environment will be suitable for manned operations on the surface if the personnel are properly protected and equipped.
- 3. All orbital operations will be carried out in a 96-minute (307-nautical-mile-high) equatorial orbit of the earth.
- 4. An equatorial launch site will be developed and funded as a part of this program.
- 5. An elaborate orbital space platform in a 96-minute equatorial orbit would be of great utility, but is not mandatory for conduct of this program.
- 6. A 24-hour communication satellite system will be in operation by 1964.

- 7. The basic carrier vehicle for this program (Saturn II) with optimized upper stages and high energy propellants can softland 6,000 pounds of cargo on the moon in one direct trip or can carry 70,000 pounds of cargo into the 96-minute equatorial orbit.
- 8. Present-day materials have been considered throughout the study with some modest improvements in the state-of-the-art consistent with the time period of interest.

The study indicates that a major lunar environment exploration program must have begun by 1962. By the end of 1964 a total of 72 Saturn vehicles should have been launched, of which 40 are expected to contribute to the accomplishment of Project Horizon. The 40 launchings will include six lunar satellites, eight lunar soft landings, seven lunar circumnavigations, four orbital return missions, and 15 operational trips for the buildup phase.

The buildup phase begins with the first orbital flight in August 1964, and the first operational cargo delivery to the moon in January 1965. Cargo will be sent to the lunar construction site directly from the earth's surface in packages of 6,000 pounds each, and via orbit in packages of 48,000 pounds each. The first manned landing is scheduled for April 1965 and will consist of a two-man vehicle with an immediate earth return capability.

The buildup program will require 61 Saturn I and 88 Saturn II launchings in a period of 28 months (August 1964 through November 1966). The total useful cargo transported to the moon will amount to 245 tons, assuming an average mission reliability of 80 per cent.

A total of 64 firings have been scheduled for the first operational year of the lunar outpost (December 1966 through 1967). An additional six Saturn I and 10 Saturn II vehicles will be assigned the mission of emergency vehicles during the entire project.

The trajectory for escape from the earth's surface is described as similar to that for injection into an elliptical transfer orbit, except that the flight path angle does not have to be 90° with the vertical. The injection angle for escape will usually be in the vicinity of 80° with the vertical.

Stairstepping toward the moon through the use of the 96-minute circular equatorial orbit offers the advantage of collecting cargo and personnel for larger moon-shot payloads and of assembling and fueling the space vehicles for greater escape impetus. It does, however, add the problem of rendezvous with the space station.

To accomplish the orbital rendezvous, the space vehicle must first be injected into an elliptical transfer orbit with extreme accuracy. Then detection and correction of errors must be accomplished for proper matching

of the space terminal orbit. Final vernier-type maneuvers will be required to obtain contact with the space terminal.

The vehicles scheduled for lunar circumnavigation will utilize the Saturn I as a carrier vehicle to overcome the earth's gravitational influence, and will incorporate a fourth stage for mid-course navigation correction on outbound and inbound trips and for the terminal maneuver near the moon.

In conducting the program, a requirement exists for the development of two types of lunar soft-landing vehicles:

- 1. A vehicle assembled or fueled in an earth orbit which departs from there for lunar surface.
- 2. A vehicle which will depart from the earth's surface, as an upper stage and payload of the basic carrier vehicle, and will go directly to the lunar surface.

Although the vehicles themselves may differ in size and shape, the same basic problems as well as system equipment requirements exist in both configurations.

All personnel going to the moon would be transported through the 96-minute equatorial orbit. Approximately two thirds of the cargo would be delivered directly to the moon, and the remaining one third via equatorial orbit.

Following the survey of a variety of locations both within and outside the continental United States it is concluded in the study that an equatorial launch site is economically feasible and technically desirable for Project Horizon. It is pointed out that from a consideration of the needs of this project alone an equatorial launch site is justified, since equatorially-launched direct flights from earth to moon alone may save enough to offset the fixed installation costs.

Further points are presented supporting the need for an immediate program to establish an equatorial launch site:

- A statement of future plans and forecasted capabilities of the Atlantic Missile Range and the Pacific Missile Range indicates very clearly that neither could handle the launch site requirements for the project.
- 2. An equatorial launch site would materially enhance the capabilities of the U. S. in space flight for all operations.



- 3. Anticipated space flight missions such as the establishment of an orbital station, an equatorial communication satellite system, and others requiring either an equatorial orbit or rendezvous capability clearly indicate the desirability of an equatorial launch site.
- 4. Preliminary computations indicate that direct flights by the Saturn II vehicle can be accomplished from non-equatorial launch sites during only about 15 days per month.

General criteria for equatorial launch site selection include:

- 1. Open water should extend to about 1500 miles downrange.
- 2. Eastward launchings should be possible.
- 3. The site should be of sufficient size to permit future growth.
- 4. The site should have at least 30 degrees azimuth traverse north and south of east.
- 5. The area downrange should include areas of land sufficient in size for installation of tracking facilities.
- 6. Proximity to the U.S. is desirable to meet logistic requirements.
- 7. Freedom from extreme climatic conditions is essential.
- 8. Site should be reserved for exclusive use of U. S.
- 9. The area should be within range of military security.
- Sea traffic in the downrange direction should be modest.

Other factors to be considered are soil characteristics, altitude, water supply, labor forces, local construction materials, and personnel recruitment.

Launch site facilities are discussed at length.

Four possible equatorial launch sites are discussed: Somalia, 0° latitude; Manus Island, South 2° latitude; Christmas Island, North 1° 59'; and the Amazon mouth, Brazil, South 2° latitude.

Somalia and Manus Island are dismissed primarily because of their remoteness from the United States, while Christmas Island and the Brazil site are discussed as to transportation distances, climatological and meteorological conditions, temperature, rainfall, air movement, hygienic conditions, soil, regional development, labor available, construction

materials available, food supplies, water supply, power and fuel, and transportation facilities. It is concluded that both Christmas Island and Brazil should satisfy the general criteria for equatorial launch site selection.

The study outlines a need for engineering studies of a chosen equatorial launch site to have been started in the last half of 1959 if the required facility is to be ready in time to meet the firing schedule. Actual construction of the service and logistic facilities should have been started by the end of 1959. The launching pads and blockhouses should have been started by mid-1960. The first firing from the site is scheduled to be in January 1963, at which time two pads and one blockhouse should be completed. The entire complex is not scheduled for completion until the end of 1965.

The following general conclusions are reached:

- 1. The establishment of a lunar outpost is technically and economically feasible.
- 2. The payload capabilities of the Saturn family makes it feasible to land the first two people on the lunar surface by spring of 1965 and to have a 12-man permanent outpost operational by November 1966.
- 3. The probability of success and the chance of survival of the personnel involved justify immediate initiation of the program, which requires only modest improvements of the state-of-the-art.

(The major portion of the study, Project Horizon, is omitted from this abstract as providing little assistance in the present study.)

I. Payload Loss for Equatorial Orbits Due to Non-Equatorial Launches, PMR-TM-59-4, Pacific Missile Range, Point Mugu, Calif., 29 July 1959

The primary purpose of this study is to provide estimates of satellite payload losses due to attaining equatorial orbits from non-equatorial launch sites. It is an expanded version of an earlier study by the same title dated 2 April 1959.

A payload loss is expressed in the study as a per cent, and it is calculated by comparing the payload which can be put into equatorial orbit from an equatorial launch to the payload which can be put into orbit from any other latitude while using reasonably identical spacecraft and launching equipment.

Computations in the study were simplified by dealing only with the final stage which executes the maneuver of interest, by assuming that all maneuvers required to go from a non-equatorial ballistic trajectory to an equatorial satellite orbit are accomplished by instantaneous impulsive velocity, by assuming that all parameters will remain constant through all latitudes, and by ignoring the effects of the earth's rotation and the possible need for heavier structural, guidance, and control equipment at greater latitudes.

Computations are provided which ascertain the payload losses for each of two methods of attaining the equatorial orbit from non-equatorial launches:

- 1. The apogee transfer.
- 2. The circular orbit transfer.

Computations are based on the following parameters as related to latitude: (1) great circle range to apogee, (2) apogee-orbit altitude, (3) ratio of the apogee velocity to the circular orbit velocity, (4) fuel specific impulse, and (5) structural factor.

The study includes a breakdown of the formulae provided for computing payload losses, and gives background for attacking the problem while employing either of the two launch methods.

Tables of payload loss computations from 0.5° to 5° latitudes at half-degree intervals, from 5° to 10° at one-degree intervals, from 10° to 20° at two-degree intervals, and from 20° to 29° at three-degree intervals are presented for many combinations of the following levels of the five key parameters:

Great circle range to apogee: 1,000; 1,500; 2,000; 2,500; 3,000; 4,000; 5,000; 6,000 statute miles.

Apogee-orbit altitude: 300; 400; 500; 600; 700; 22,300 statute miles.

Ratio of the apogee velocity to the circular orbit velocity: 0.5; 0.6; 0.7; 0.8; 0.9; 1.0.

Fuel specific impulse: 250; 300; 350; 400 seconds.

Structural factor: 0.1; 0.2; 0.3; 0.4.

Graphs demonstrate payload loss as affected by each of the five basic parameters in both the apogee transfer and the circular orbit transfer models, as well as other factors bearing on the launching of satellites. It is concluded that low altitude equatorial satellite orbits may be produced from sites as far away as the continental United States only at the expense of most if not all of the satellite payload. Calculations for stationary orbit at an altitude of 22,251 miles show that penalties can be kept below 10 or 15 per cent for continental launch sites.

J. Departure Trajectories for Interplanetary Vehicles, NASA TN D-80, Lewis Research Center, Cleveland, Ohio, November 1959

This is a study of the problem of determining the correct magnitude and direction of the launching velocity required to reach another planet.

The problem is approached in two phases: (1) the relation between the required hyperbolic velocity and the desired initial heliocentric velocity is determined, with consideration of the effect of the inclination of the orbital plane of the destination planet.

(2) The magnitude and direction of the launch velocity needed to attain the required hyperbolic velocity is computed.

It is concluded that the launching of interplanetary vehicles from the surface of the earth is possible from any latitude, with the maximum velocity penalty corresponding approximately to loss of the benefit of the earth's rotational speed. Sample calculations indicate that most of the earth's rotational speed can be realized at any latitude if the launching time during the launch day is properly selected. In some instances, launchings from non-equatorial sites require slightly smaller velocities than equatorial launchings.

Launching interplanetary vehicles from closed orbits around the departure planet may impose much more severe velocity penalties, relative to coplanar values, than launching from the planet's surface, since the satellite velocity is much higher than the surface rotational speed.

However, if the selected departure-orbit plane is parallel to the hyperbolic orbit plane, the total velocity increment may be slightly less than for surface launching. Such departure orbits can be attained from any surface launch site.

The best launching latitude for interplanetary vehicles is found to depend strongly upon the trajectory to be followed, and is not necessarily the equator.

K. Equatorial Launch Site Study (Classified), Space Technology Laboratories, Inc., Los Angeles, California, 25 March 1960

A technical analysis is made in this report of velocity loss associated with firing various payload weights into equatorial orbits from equatorial and non-equatorial launch sites. Optimum exit azimuths and transfer ellipses to achieve equatorial orbits from non-equatorial launch sites are considered. Also, exit azimuths necessary to accomplish deep space probes, such as moon rendezvous and impact on the various planets, are considered for equatorial and non-equatorial sites.

Advantages of an equatorial launch site versus non-equatorial launch sites are considered in detail for the Communications Satellite Program. Other planned programs which would benefit from an equatorial launch site are discussed.

Limitations of the present launch facilities at AMR and PMR are analyzed on the basis of program restrictions imposed by range safety considerations. Several equatorial launch sites are considered on the basis of Stage I and Stage II impact of booster vehicles, and each is analyzed, first, on the range safety basis of these impacts and the availability of exit azimuths from 0 to 180° .

Economic considerations of program accomplishment of equatorial versus non-equatorial launch sites are analyzed; and logistics, security, and defense aspects of launching from particular equatorial sites are reviewed.

It is pointed out that lunar and interplanetary launches are no more difficult to launch from high latitudes than from the equator, but that equatorial sites would be beneficial for low orbits, range safety, and simplified recovery and tracking techniques.

L. Selection of an Equatorial-Launch Site, PMR-TM-60-13, Pacific Missile Range, Point Mugu, Calif., 28 December 1960

This study is an attempt to determine the best possible location for a missile launch site on or near the equator.

The following criteria are utilized in screening possible equatorial locations:

- 1. It must be on land.
- 2. It must be capable of serving many diversified range requirements.



- 3. It must be located within 9 degrees of the equator.
- 4. Rainfall at the site must not exceed 50 inches per year.
- 5. A suitable tracking site must be available.
- 6. Down-range impact corridors must be available which will not endanger inhabited areas.
- 7. The site must be suitable for the use of nuclear and exotic propellants, including those of a highly toxic nature.
- 8. It must be suitable for the use of multiazimuth launch headings.
- 9. It must have an acceptable political background.

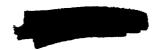
The study quickly confines the site search area to a sector lying between $151^{\rm O}$ west and $174^{\rm O}$ east longitude and between $2^{\rm O}$ north and $9^{\rm O}$ south latitude in the Pacific Ocean. This sector is bounded on the north and west by climatical criteria, on the south by down-range safety considerations and the $9^{\rm O}$ south parallel, and on the east by down-range tracking requirements.

After setting up a minimum area limitation of three square miles, the study sifts through islands in what is considered the generally suitable geographical area. The following are selected for further consideration: Canton Atoll, Malden Island, Starbuck Island, Penrhyn Atoll, Abemama Atoll, Kuria, Aranuka Atoll, Nonouti Atoll, Tabiteuea Atoll, Beru, Nikunau, Onotoa Atoll, and Arorae.

Each of the thirteen possible sites is given a cursory study as to facilities for launching, air and sea transportation, instrumentation, maintenance, industrial activities, and housing.

A comparison of the results from the preliminary study indicates that Canton Atoll, Malden Island, Abemama Atoll, and Nonouti Atoll are more desirable than others in the area. These four are studied further, and charts are provided to outline configuration, development plans, firing azimuths, and range clearance for each.

Canton Atoll at 2° 46' south, 171° 43' west, has a land area of about 4.0 square miles, with a lagoon area of about 20 square miles. It is low and flat, with warm easterly winds. It has about 19 inches of rainfall per year, and is grown up with low scrub or grass. It has 7,000-by-150-airstrip with 1,900-foot overrun. There is a natural harbor on the west side with a controlling depth of 27 feet. There is a hospital and an administration building. It is 3,650 nautical miles



from Point Arguello, with ample safety area 5,000 miles eastward. About 340 persons live on the island, and both the United States and England have rights of use.

Malden Island, 4° 03'S, 155° 01'W, has a land area of 11.3 square miles. It is low and flat, with about 27 inches of rainfall per year which supports sparse scrub grasses and low bushes. There are no facilities, and the island is uninhabited. There is no land for thousands of miles in an arc from north to east-southeast. It lies 3,020 nautical miles from Point Arguello. It is claimed by both the United States and the United Kingdom.

Abemama Atoll, 0° 21' N, 173° 51' E, has a land area of about 6.57 miles, with another 11 square miles in two neighboring atolls. It is low and flat, with about 50 inches of annual rainfall which supports coconut palms and low scrub. There is no airstrip, but there is ample lagoon anchorage with 35-foot depths. No other facilities exist. Approximately 2,000 persons live on the three atolls, which are colonies of the United Kingdom. The atolls lie 4,200 nautical miles west of Point Arguello.

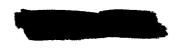
Nonouti Atoll, 0° 41'S, 174° 27'E, has a land area of about 9.9 square miles in a very long, narrow island lying along the east side of a 10- by 24-mile lagoon. It is low and flat, with about 43 inches of annual rainfall. Coconut palms and low scrub grow on the island, which supports a population of 1,900 persons. The channel to the harbor in the lagoon is 24 feet deep. There are no other facilities. It is a colony of the United Kingdom and is located 4,200 nautical miles from Point Arguello.

The study concludes that Canton Atoll should make the best available equatorial launch site, because the airfield and harbor facilities are in operation, a sheltered seaplane basin is usable for recovery operations, weather conditions are best among the sites considered, and early acquisition appears feasible.

M. Long Range Planning for Space Transportation Systems, NASA TN D-597, George C. Marshall Space Flight Center, Huntsville, Ala., January 1961

The purpose of this study is to present current concepts of the Future Projects Office at the George C. Marshall Space Flight Center in the area of long-range planning, as well as to discuss the major system parameters of importance to future launch operations.

The long range objective of the National Aeronautics and Space Administration space flight program is the manned exploration of the moon and the planets.



The study explores the following fields of space flight development: program requirements, resources, cost relationships, integrated program requirements, resources and program balance, and trends of space transportation cost.

The following are described as areas of major decisions: Saturn C-2 program, orbital operations program, Saturn long-range improvement (C-3), use of F-1 engine (Nova?, C-3?), launch vehicle final objective within the state-of-the-art, manned lunar landing, manned planetary exploration and nuclear propulsion.

Typical payload requirements for possible future requirements are estimated in equivalent weights for a 300-nautical mile orbit:

1.	Construction of a 6-man space laboratory	100,000 lbs
2.	Logistic support of a 6-man space laboratory (annual)	200,000 lbs
3.	Construction of a 50-man space station	1,000,000 1bs
4.	Manned lunar circumnavigation	1,000,000 lbs
5.	Manned lunar landing of a 3-man crew and return	1,000,000 lbs
6.	Construction of a 10-man lunar observatory	6,000,000 lbs
7.	Establishment of a 24-hour communication satellite system	200,000 lbs
8.	Logistic support of a 10-man lunar observatory (annual)	3,500,000 lbs
9.	15-man fast planetary expedition	6,000,000 lbs

Typical firing rates for various space vehicles, funds available for space missile development, possible mission accomplishments, launch vehicle development rates, estimated pad times required, mission reliabilities, annual transport volume capabilities, and other factors are discussed.

It is suggested that no larger vehicle than the Saturn is required for transport of volumes up to 3,000,000 lbs per year.

The following conclusions are presented:

- It is very likely that the Atlantic Missile Range and Pacific Missile Range will be able to handle all launch operations within the foreseeable national space flight program provided nuclear safety requirements can be satisfied.
- The launch pad utilization for space vehicles has developed into one of the most important system parameters, and a great effort to reduce the launch time for each vehicle seems justified.
- N. Residual-Load-Plus-Powerplant Weights for Orbital-Launch Nuclear Rockets, NASA TN D-843, May 1961

This is a presentation of the results of a parametric study of orbital-launch nuclear rockets.

The primary variables are (1) mission requirements, (2) initial weight in orbit, (3) thrust, and (4) specific impulse.

To illustrate the effect of varying mission energy requirements, the following hypothetical missions are used: (1) escape from earth, (2) 75-day Venus probe, (3) 100-day Mars probe, (4) 413-day Jupiter probe

(5) 125-day trip to Mars orbit, and (6) 100-day trip to Mars orbit.

Initial weights in orbit are 7,600; 18,000; 42,700; 77,000; and 226,000 lbs.

Ranges of thrust and specific impulse are selected which include all anticipated values of interest. Values of thrust vary so that ratios of thrust to initial weight lie between 0.01 and 1.0. Specific impulses of 450, 600, 800 and 1,000 seconds are illustrated.

Charts are presented of residual-load-plus-powerplant weight as a function of thrust, specific impulse, initial weight in orbit, and mission energy for orbital-launch nuclear rockets.

The charts and curves presented are intended to be useful during the formative period of nuclear-rocket research and development. They are expected to give ready-reference indications of allowable power-plant weights or residual loads for typical applications of orbital-launch nuclear rockets, and to assist in estimation of desirable power levels and operating conditions.

O. A Geoid and World Geodetic System Based on a Combination of Gravimetric,

Astrogeodetic, and Satellite Data, NASA TN D-702, May 1961 (Presented at 12th General Assembly of the International Union of Geodesy and Geophysics, Helsinki, Finland, July 1960)

This analysis attempts to make the best possible combination of available gravimetry, astro-geodetic networks, and secular or long period satellite motion determination in order to estimate (1) the earth's external form and gravitational field as expressed in spherical harmonics up to the eighth degree, (2) the equatorial radius and flattening of the ellipsoid, and (3) the positioning of the principal geodetic systems.

The gravimetric data utilized cover approximately 20 percent of the earth's surface in the form of mean free-air anomalies for 1 by 1 degree squares which are extended by use of Markov analysis to give an estimated anomaly for all 10 by 10 degree squares. For twelve 10 by 10 degree squares in Asia where Zhongolovich had much more data, his mean anomalies are used. A direct harmonic analysis is made of the mean anomalies of the 10 by 10 degree squares to obtain 81 harmonic coefficients of degrees zero through eight. These coefficients constitute the gravimetric observations used in the computation.

Other observations are also employed, including the satellite data from the secular motions of node and perigee and the periodic variations of node, perigee, and eccentricity of 1958 β , and the secular motion of the node of 1957 β .

One hundred condition equations are used, including five different types: (1) Amur geoid match, (2) equatorial radius, (3) geoid height differences, (4) inadmissible harmonics, and (5) satellite motions.

The 196 observations which are employed include four different types: (1) Amur geoid match, (2) astro-geodetic geoid height differences, (3) gravity harmonic coefficients, and (4) satellite motions.

The results obtained include: equatorial radius, 6378163 ± 21 meters; flattening, $1/298.24 \pm 0.01$; equatorial gravity, 978043.6 ± 1.2 milligals (Potsdam system).

It is concluded that improved results will depend on additional observational data--in particular a more extensive gravity coverage from either airborne gravimetry or more precise measurement of satellite orbit variation. The extension of geodetic control to new locations will yield some improvement. A reconciliation of the radius estimate from terrestrial data with that from lunar distance measurement is needed.

P. Safety and Design Considerations for Static Test and Launch of Large Space Vehicles (Classified), MT 61-11634, Joint Air Force-NASA Hazards Analysis Board, 1 June 1961

The objectives of this study are: (1) to define the hazards associated with the launching of large space vehicles; (2) to analyze each hazard; (3) to develope preliminary design data upon which to base plans and decisions regarding the siting and safety considerations for space vehicle launch facilities, equipment, instrumentation, and personnel; and (4) to determine the precautions necessary to prevent undue hazards to the civilian population in adjacent uncontrolled areas.

The report presents preliminary information collected from recognized experts who contributed design data and considerations regarding the hazards of blast, acoustics, fire, fragments, radiation, and toxicity. Since vehicle systems have not been defined, six representative vehicles with liquid, solid, and nuclear systems are assumed as follows: (1) the Saturn C-3, a four-stage liquid-fuel vehicle with an escape payload potential of 40,000 lbs; (2) a four-stage solid-fuel vehicle with an escape payload potential of 80,000 lbs; (3) a four-stage combimation vehicle with a nuclear third stage and with liquid-burning booster, second, and final stages, capable of escape payload of 182,000 lbs; (4) a combination vehicle with solid-fuel booster and three liquidfuel upper stages, capable of escape payload of 130,000 lbs; (5) a fourstage liquid-fuel vehicle capable of escape payload of 130,000 lbs; and (6) a combination vehicle with a solid-fuel booster and second stage and two liquid-burning upper stages, capable of escape payload of 170,000 lbs.

A hazard analysis table for each of the six defined vehicles is presented with data pertinent to the hazards under study.

Booster thrust for the six vehicles range from 3,000,000 lbs to 37,000,000 lbs; total pounds propellants, 2,590,000 lbs to 23,000,000; and potential escape payload range from 40,000 to 182,000 lbs.

Blast hazards range as follows: (1) equivalent TNT blast potential, 377 to 3,300 tons; (2) interpad separation to protect missiles ($P_s=0.75$ psi), 4,000 to 10,000 feet; (3) launch danger for nonessential personnel ($P_s=0.4$ psi), 8,640 to 17,600 feet; and control area limit 17,300 to 35,600 feet.

Acoustic hazards range as follows: (1) control area limit, 12,000 to 50,000 feet; and (2) windowless conventional building limit within control area, 7,000 to 30,000 feet.

Fire hazards remain constant at 750 feet radius.

Fragment hazards remain constant at 5,000 feet radius.



Radiation hazards are present in only one vehicle. Control limit is set at 52,800 feet, with personnel evacuation within 10,560 feet.

No toxic hazards are envisioned.

Each of the hazards is discussed at length, with emphasis on biological and structural safety factors, medical aspects, and legal responsibilities. Charts and graphs provide guidance data.

Need for an intense public relations program centered about the launch areas is outlined.

It is acknowledged that much of the information presented is preliminary to more intense studies.

It is concluded that:

- 1. Launching of large space vehicles, from on shore at Cape Canaveral, is possible provided additional land is acquired on Merritt Island to extend the control area.
- 2. The hazards imposed by liquid and solid systems dictate separation distances from launch site to civilian population up to 35,000 feet.
- 3. Nuclear ≡ upper stage ≡ systems dictate separation distances from the launch site to civilian population of at least 10 miles.
- 4. Operational hazards for liquid and solid boosters do not dictate going to off-shore launch sites. Future nuclear-powered boosters may require off-shore or other remote launch sites.
- 5. Additional land acquired, which provides buffer zones to the uncontrolled civilian populace, is suitable for industrial and technical support use.
- 6. Public information programs to educate and condition the civilian populace and controlled area personnel to the operational hazards are needed immediately. These programs will alleviate fears and suspicions regarding the nature and magnitude of the hazards involved.
- 7. Additional studies to develop better data are necessary in all the hazards areas.
- 8. Meteorological conditions will have definite impact on the land area subjected to a given hazard.





- 9. People within the controlled area can be protected from launch hazards by evacuation, special conventional construction, and blast-resistant construction.
- 10. No nuclear explosion is possible from the assumed nuclear rocket system.
- Q. Saturn C-2 Operational Modes Study Summary Report (Classified), ER 11629, George C. Marshall Space Flight Center, June 1961

This is a study of the technical and economic requirements of the Saturn C-2 space vehicle.

Three different launch rates over a ten-year period are considered:

- 1. A total of 111 vehicles, with a peak annual launch rate of 12.
- 2. A total of 330 vehicles, with a peak annual launch rate of 48.
- 3. A total of 666 vehicles, with a peak annual launch rate of 120.

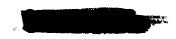
Seven basic operational areas are investigated: production, stage static firing, stage transportation, propellant supply, prelaunch check out, launch operation, and flight evaluation.

Three methods of launch operation are studied:

- 1. Movement of the launch vehicle to the pad in a vertical position.
- 2. All assembly and checkout on the launch pad.
- 3. Horizontal checkout and electrical mating in the pre-launch area, with vertical assembly and checkout on the launch pad.

Certain pertinent ground rules are outlined:

- 1. All launches will be downrange.
- No more than one launch vehicle will be on a complex at one time.
- 3. The dual launch pad concept has been accepted as preferable to a single launch pad.





Conclusions and recommendations: 1

- 1. Production is by far the most costly of the operational areas in the study, incurring from 73 to 75 per cent of the total cost. Next most costly is the AMR Range Operation Costs, which vary between 18 and 21 per cent.
- 2. Remote production of individual stages in existing facilities is slightly less costly that the method involving stage final assembly at new facilities near Cape Canaveral. However, when considered in conjunction with static firing and stage transportation costs, the combined operation at new Cape Canaveral facilities would be less expensive.
- 3. It is desirable to construct new production facilities for the cryogenics (hydrogen, oxygen, and nitrogen) on site at Cape Canaveral.
- 4. Direct assembly and checkout on the launch pad is the most efficient and least costly for low launch rates. However, for higher launch rates it is preferable to develop a system whereby the vehicle is assembled and checked out in the vertical position at an off-complex prelaunch area, then delivered in this position to the launch pad.

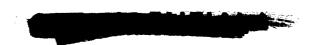
(The major portion of ER 11629 is omitted from this abstract as irrelevant to the present study.)

R. <u>Earth Oblateness and Relative Sun Motion Considerations in the Determination of an Ideal Orbit for the Nimbus Meteorological Satellite</u>, NASA TN D-1045, July 1961

This study outlines the procedure for maintaining the Nimbus meteorological satellite in a polar orbit in which it will always alternately cross the equator at noon (local time) and at midnight (local time) at half-orbit intervals.

The Nimbus meteorological satellite is described as carrying improved television, radiation, and other types of experimental equipment in a 600-nautical-mile circular orbit about the earth for a nominal instrumental lifetime of six months.

It is believed that these conclusions and suggestions may contribute indirectly to the determination of the logistical, funding, and functional requirements of any possible equatorial launch site.



Calculations are outlined to utilize the distortion of the earth's gravitational field due to the oblateness of the earth in establishing the necessary nodal regression to maintain the desired orbit. It is ascertained that an ideal circular orbit will be 600 nautical miles (691 statute miles or 1,112 kilometers) above the earth. It will have an inclination of 99.89 degrees and a time period of 107.4 minutes, with 13.41 orbits per day.

Under these conditions the phenomenon of nodal regression due to the earth's oblateness will maintain the orbit in such a manner that the line of nodes advances (eastward) along the celestial equator at the same rate as the mean sun, i.e., 0.9856 degrees per day.

Thus such a noon-midnight orbit would continue indefinitely.

S. Equatorial and Mobile Launch Operations and Facilities (Classified), CA 61-61, U. S. Department of the Navy, 9 August 1961

The purpose of this report is to determine (1) if an equatorial launch facility is now desirable, and (2) what type facility should be made available for equatorial launches.

Launching programs utilizing the following launch site concepts are considered as to costs and functional characteristics:

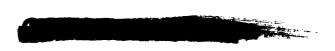
- 1. Atlantic Missile Range (AMR).
- 2. Remote equatorial island site.
- 3. A mobile drydock site for use adjacent to a land mass.
- 4. A fully mobile launch ship.

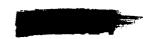
It is pointed out that a cost comparison based only on initial installation and operation is not realistic, as such factors as type of mission, need for mobility, and wide variation in time required for construction are also crucial.

The report is limited to the consideration of liquid-propellant boosters of the ICBM class, but it is acknowledged that other space vehicle programs might be expected to make use of any new facilities.

Two specific programs are selected for study:

- 1. An Atlas-Centaur to boost a satellite into a synchronized 19,200-nautical-mile equatorial orbit.
- 2. An Atlas-Agena to boost a satellite into a 5,600-nautical-mile circular equatorial orbit.





The report points out that the payload penalty for placing a satellite into an equatorial orbit from a non-equatorial launch site increases with decreasing orbital altitude, becoming almost prohibitive for low orbits (200 to 500 miles) below the Van Allen belt where many future manned operations are expected.

The report cites the following projects which should benefit from a mobile equatorial launch site: ADVENT, AEROS, ANNA, APOLLO, ARENTS, DEFENDER, DYNA-SOAR, EARLY SPRING, MARINER, OSO, PROSPECTOR, RANGER, RELAY, SAINT, SURVEYOR, SR-178, TRANSIT, VELA HOTEL, VOYAGER, and YO-YO.

The following are listed as potential vehicles for fixed equatorial or mobile launches: Boosters--Atlas, Minuteman, Nova, Polaris, Redstone, Saturn, Scout, Thor, Titan II. Upper stages--Able Star, Agena B, Centaur, Delta, and new upper stages using fluorine or solids.

Estimated relative cost summary for an 8-year program, in millions of dollars, is presented:

	AMR COMPLEX		D SITE N ISLAND)	SEMI-MOBILE DRYDOCK	LAUN SHI	
		First	,		2 Ships	
		Clas s	Austere			
CAPITAL INVESTMENT						
EXISTING FACILITIES	46.00			30.00		
NEW FACILITIES		72.20	56.40	15.70	161.00	87.00
TOTAL FACILITIES	46.00	72.20	56.40	45.70	161.00	87.00
ANNUAL OPERATING AND						
MAINTENANCE COST	14.20	21.00	16.60	16.40	16.70	10.90
OPERATING COST						
PER LAUNCH		2.62		2.05	2.08	
VEHICLE COST	3.00	3.00		3.00	3.00	3.00
TOTAL COST PER LAUNCH	4.77	5.62	5.08	5.05	5.08	4.37
NET WEIGHT						
IN ORBIT (LBS)	(800)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)
COST PER LB						
(THOUSANDS)	5.96	4.68	4.23	4.21	4.24	3.64
SAVINGS PER LB						
(THOUSANDS)		1.28	1.73	1.75	1.73	2.32
(YEARS FOR PROJECT						
TO PAY FOR ITSELF						
AT 8 LAUNCHES PER		(5.9)	(3.4)	(2.7)	(9.6)	(3,9)
YEAR)						

Studies and analyses are completed for each of the four launch complexes in the following areas: vehicle performance, cost comparisons,

guidance, factory to launch sequence, logistics, safety, supporting instrumentation, propellant handling and storage, and special factors.

The study outlines certain advantages and disadvantages of the new launch complex studies under consideration as compared to existing facilities at the Atlantic Missile Range:

1. General employment of fixed equatorial or mobile launch facilities.

a. Advantages:

- (1) An increase in available payload weight as a result of velocity gain from elimination of dogleg, utilization of maximum earth rotation, and possible reduction of fuel and oxidizer boil-off during coast period.
- (2) Relief of possible saturation of present facilities.
- (3) Easier access to a rendezvous orbit.
- (4) Greater range safety.
- (5) Mobility for certain tactical missions.
- (6) Possibility of remote launchings for very large or nuclear boosters.

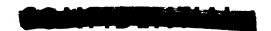
b. Disadvantages:

- (1) More costly operations (except for the drydock concept).
- (2) Greater logistic requirements.
- (3) Possible political difficulties.

2. Fixed Site (Island).

a. Advantages:

- (1) Least change from present operating concepts and AGE.
- (2) Ready availability of facility designs for launch complex.



(3) Most nearly normal community support for civilian personnel, with relatively unlimited space.

b. Disadvantages:

- (1) Fixed location.
- (2) High construction cost compared to U. S.
- (3) High cost for AGE installation and checkout.
- (4) Need of approval of controlling government.

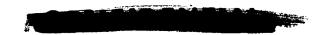
3. Semi-Mobile Site (Drydock):

a. Advantages:

- (1) Availability of stateside construction, repair, and modification.
- (2) Moderate AGE redesign.
- (3) Availability of power, cranes, and some community facilities already on drydock.
- (4) Usability of island for any part of technical, instrumentation, community, or air support.
- (5) Shorter possible lead time than fixed site construction.
- (6) Possibility of construction of replacement launch complexes for new programs in the United States while existing complex is in use.

b. Disadvantages:

- (1) For self-contained operation all community, technical, and range support must be carried aboard or on accompanying vessels.
- (2) Long replacement time for damaged facilities in case of major casualty.
- (3) Requirement for development of integrated system for self-contained operation.



4. Mobile Launch Site (Ship):

a. Advantages:

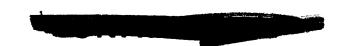
- (1) Ability to select any launch point.
- (2) Possibility of covert launch.
- (3) Vehicle checkout at factory.
- (4) Availability of existing range instrumentation.
- (5) Possibility of quick response to unusual launch requirements.
- (6) Ease of collaboration with foreign space efforts.
- (7) Stateside construction, repair, and modification.

b. Disadvantages:

- (1) Limited living and work space.
- (2) Need for development of AGE to meet shipboard environment.
- (3) Long replacement time for damaged facilities in case of major casualty.
- (4) Need for development of a new launch system.
- (5) Need for procurement of a ship and facilities not associated with the actual launch.
- (6) Greater hazard factor than land operations.
- (7) Long lead time (ship construction schedule, 48 months).

The study offers the following conclusions and suggestions:

- The United States should immediately undertake the development of a drydock launch complex, as this will best provide an early and economical equatorial launch capability for the specific cases studied.
- 2. The benefits to be derived in both technical gains and longterm economic advantages point to a definite and immediate need for an equatorial launch facility.



- 3. The number of programs which will benefit from an equatorial launch site will materially increase in the future.
- 4. Launches from each of the three new concepts considered in the study are technically feasible and economically reasonable.
- 5. The new concepts are most adaptable to booster classes as follows:
 - a. Launch Ship--IRBM, ICBM Types.
 - b. Drydock--ICBM, Saturn, Nuclear.
 - c. Equatorial Island -- ICBM, Saturn, Nuclear, Nova.
- T. A Study of Six-to-Twelve-Million-Pound-Thrust Launch Vehicles (Classified), AE61-0567, General Dynamics/Astronautics--A Division of General Dynamics Corporation, 15 August 1961

This is a comprehensive systems study which was completed in order to establish some of the parameters needed to define the next generation of launch vehicles after Saturn. It was undertaken to assist the National Aeronautics and Space Administration in the planning of a national booster program.

The study scrutinizes 20 NASA-specified launch vehicle configurations in order to determine eligibility and priority for the program. The configurations are considered as to capability, reliability, early availability, and cost.

The study was accomplished in three phases.

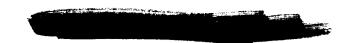
The first phase, 1 February 1961 to 17 April 1961, deals with reliability, performance, preliminary system costs, and costs per payload pound for chemical-powered vehicles.

The second phase, 18 April 1961 to 7 June 1961, deals with the designs of the chemical-nuclear vehicles in relation to attaining escape velocity instead of orbital velocity, and with two stages instead of three.

The third phase, 8 June 1961 to 10 July 1961, deals with air and ground loads analyses, stress analysis, weights analysis, and revised performance work for six high priority vehicles, which are described briefly as follows:

TABLE IV-1. SELECTED PARAMETERS PERTINENT TO THE CONSTRUCTION AND OPERATION OF SIX SIX-TO-TWELVE-MILLION-POUND-THRUST LAUNCH VEHICLE CONFIGURATIONS CHOSEN FOR HIGH PRIORITY DEVELOPMENT SCHEDULES IN REPORT NUMBER AE61-5067

Availability Date	Apr '68	Mar '66	Mar '66	Dec '67	May '71	May '66
Ava	∢	Σ	2	н	_	2
Mission Relfability	0.685	0.680	0.675	0.690	0.750	0.660
Ideal Velocity (fps)	41,700	41,840	41,770	41,900	42,280	42,400
Thrust (1bs)	12,000,000 5,600,000 200,000	12,000,000 3,460,000 800,000	12,000,000 3,460,000 800,000	T/W = 2 5,600,000 200,000	12,000,000 760,000	12,000,000 1,600,000 200,000
Isp	265/305 426 426	265/305 305 426	265/305 305 426	245/263 426 426	265/305 820	265/305 426 426
Type of Motors	F-1 Y-1 J-2	F-1 J-2	F-1 J-2	Solid Y-1 J-2	F-1 4000-MW	F-1 J-2
Number of Motors	8 4 1	8 7 4	8 7 7	Solid 4 1	60 4	8 8 7
Orbital Payload (1bs)	452,000	409,000	•	389,000	ı	311,000
ا ټا			0	0	8	9
Escape Payload (1bs)	235,000	166,000	163,000	210,000	318,000	186,000
Wruel Escape (1bs) Payloa (1bs)	8,815,000 235,000 5,760,000 2,515,000 540,000	8,984,000 166,000 6,400,000 1,708,000 876,000	8,873,000 163,000 6,400,000 1,625,000 848,000	10,210,000 210,00 7,110,000 2,620,000 580,000	8,716,000 318,0 7,718,000 1,002,000	8,946,200 186,007,200,000 1,328,800 416,400
			851,115 8,873,000 163,000 6,400,000 1,625,000 848,000	1,724,613 10,210,000 7,110,000 2,620,000 580,000		
Whry Wruel (1bs)	159 812,159 8,815,000 5,760,000 2,515,000 540,000	8,984,000 6,400,000 1,708,000 876,000	8,873,000 6,400,000 1,625,000 848,000	10,210,000 7,110,000 2,620,000 580,000	8,716,000 7,718,000 1,002,000	8,946,200 7,200,000 1,328,800 416,400
WFuel (1bs)	159 812,159 8,815,000 5,760,000 2,515,000 540,000	,914 747,914 8,984,000 6,400,000 1,708,000 876,000	3 9,724,115 851,115 8,873,000 6,400,000 1,625,000 848,000	1,724,613 10,210,000 7,110,000 2,620,000 580,000	2 9,718,969 1,002,959 8,716,000 7,718,000 1,002,000	792,128 8,946,200 7,200,000 1,328,800 416,400

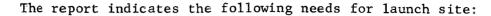


- 1. No. 1--three-stage, with eight F-1 engines in the booster, four F-1H engines in the second stage, and one J-2 engine in the third stage; booster thrust, 12,000,000 lbs; escape payload, 235,000 lbs; availability, April 1968.
- 2. No. 2--three-stage, with eight F-1 engines in the booster, two F-1 engines in the second stage, and four J-2 engines in the third stage; booster thrust, 12,000,000 lbs; escape payload, 166,000 lbs; availability, March 1966.
- 3. No. 2B--three-stage, with eight F-1 engines in the booster, two F-1 engines in the second stage, and four J-2 engines in the third stage; booster thrust, 12,000,000 lbs; escape payload, 163,000 lbs; availability, March 1966.
- 4. $\underline{5A}$, $\underline{5B}$, $\underline{5C}$ --three-stage, with solid fuel booster, four Y-1 engines in the second stage, and one J-2 engine in the third stage; booster thrust, T/W = 2; escape payload, 210,000 lbs; availability, December 1967.
- 5. No. 9--two-stage, with eight F-1 engines in the booster and four 4000 MW nuclear engines in the second stage; booster thrust, 12,000,000 lbs; escape payload, 318,000 lbs; availability, May 1971.
- 6. No. 14A--three-stage, with eight F-1 engines in the booster, eight J-2 engines in the second stage, and one J-2 engine in the third stage; booster thrust, 12,000,000 lbs; escape payload, 186,000 lbs; availability, May 1966.

Construction details are developed for the six high priority vehicles, structures trade-offs are studied, systems requirements are determined, heating and dynamics problems are studied, development and funding plans and schedules are worked out, and transportation, launch facility, and operational requirements are investigated.

Vehicle 14A is recommended in the study, though there are few apparent differences between this vehicle and vehicles 2 and 2B. The main advantage of 14A over 2 and 2B is in the growth potential; that is, it has more first stage propellant and payload capability than the latter two and would be most suitable for use with a nuclear second stage similar to Vehicle 9.

Vehicles 2 and 2B have an edge of approximately sixty days in operational availability over 14A, but this slight advantage is considered insignificant in view of the fact that the availability date of launch site may be the pacing item in the entire program.



- 1. It should be located at least 20 miles from any uncontrolled population to insure a nominal maximum of 115 decibels of noise. Personnel under direct control of the operating agency could be located 2 to 5 miles distant and be ordered to take cover prior to launch.
- 2. It should be on a remote shoreline or offshore above shallow water, with docking facilities available to the launch complex. An upper level for establishing a movable service tower might be established on the steep shoreline of an island near the equator, it is suggested, where more efficient mission performance might be expected in comparison to a non-equatorial site.
- 3. Facilities must be provided for on-site vertical assembly of the rocket configurations.
- 4. Two launching pads must be provided for six launchings of the 14A configuration per year; six pads for 24 launchings; and 10 pads for 48 launchings.
- 5. It is suggested that the higher cost of acquiring and utilizing a remote equatorial island might be justified in considering long-range requirements.

A construction time schedule for a launching site outlines the first flight of the 12,000,000-lb initial thrust vehicle at 44 months after contractual go-ahead. The schedule is considered optimistic when compared with construction rates on present programs. But it is pointed out that in the event that launcher construction becomes the pacing item in the overall launch vehicle program the schedule might be compressed to match the availability date of the vehicles.

(A major portion of Report No. AE61--0567 is ignored in this abstract, since it is not considered pertinent to the present study.)

U. NASA Study of Six to Twelve Million Pound Thrust Launch Vehicles (Classified), Volumes I and II, TP 64-007 FPO 61-2, Space and Information Systems Division, North American Aviation, Inc., Downey, Calif., 23 August 1961

This report covers the goals, results, and technical material developed during the National Aeronautics and Space Administration study of six-to-twelve-million-pound-thrust launch vehicles, which was commenced on 1 March 1961. The primary goal of the study was to define the most promising design concepts for the Nova-type high-thrust launch vehicles.

IV-34



TABLE NO. IV-2. SELECTED PARAMETERS FOR THREE NOVA-TYPE SPACE VEHICLES RECOMMENDED FOR DEVELOPMENT IN THE FINAL REPORT, NASA STUDY OF SIX-TO-TWELVE-MILLION-POUND-THRUST LAUNCH VEHICLES, 23 AUGUST 1961

Avaílability Date	Feb 1965	Oct 1964	May 1968
Mission Reliability	0.925	0.925	0.968
Pacing Item	2nd Stage Engine	Launch Site	Nuclear Engine
Dev. Lead Pacing Time Item (mos)	39	36	75
MPL/WG	0.214	0.0152	0.0616
Escape D Payload WpL/WG (1bs)	205,210 0.214	146,180 0.0152	473,000 0.0616
Type of Motors	F-1 1.2 M, H ₂ J-2	F-1 J-2	1.2 \overline{H}, H2 15,000 MW
Number of Motors	844	8 7 4	8 1
WFue (1bs)	8,802,000 6,355,000 1,512,000 935,600	8,949,600 6,528,000 1,839,600 582,000	6,696,000 5,683,000 1,013,000
Wbry (1bs)	718,000	650,400	984,000
WTO (1bs)	9,600,000	0,600,000	7,680,000
No. of Stages	n	က	7
Vehicle No. Number of Stages	1-3-E I II III	2-3-E I II III	17-2-E I II



The report is presented in two volumes. Volume I is a summary of the study goals and significant results. Volume II covers in detail the study goals, results, and the substantiating technical back-up materials.

Eighteen launch vehicle configurations were put under study and are considered in the report.

Three basic space vehicle configurations of the Nova type are recommended for development:

- 1. No. 1-3-E--three stages, with 8 F-1 motors on the booster, four 1,400,000-1b-thrust liquid $0_2/\mathrm{H}_2$ motors on the second stage, and four J-2 motors on the third stage; escape payload, 205,210 lbs; and availability date February 1965.
- 2. No. 2-3-E--three stages, with 8 F-1 motors on the booster, two F-1 motors on the second stage, and four J-2 motors on the third stage; escape payload, 205,210 lbs; and availability date October 1964.
- 3. No. 17-2-E--two stages, with eight 1,200,000-1b-thrust motors on the booster and one 15,000 MW reactor, 701K, H₂, on the second stage, escape payload, 473,000 lbs; and availability date May 1968.

It is suggested that Cape Canaveral would not be suitable as a launch site for the Nova-class vehicle because (1) a twenty-mile radius of controlled area is not available, and (2) even the addition of offshore facilities at that location would at best extend its launch site usefulness for a limited time.

Criteria fundamental to the selection of a launch site were described as (1) availability of full docking potential, (2) remoteness, (3) availability of service personnel, and (4) suitability of down-range azimuths and tracking facilities.

The study names the southeast end of the Hawaiian Islands as the most desirable launch site available because (1) the area is reasonably close to the equator, (2) there is no possibility of political difficulties, (3) local technical help is available, and (4) imported technical personnel would be willing to relocate in the area.

Certain areas along the Gulf Coast, particularly near Brownsville, Tex., are named as possible launch sites.

It is suggested that the launch site include facilities for vertical assembly and testing of the configurations under study. Two possible methods of assembly are discussed:

- 1. Assembly on two permanent launch pads, each with an umbilical tower. A mobile service tower would shuttle between the two pads.
- 2. Two mobile pedestal-type launching pads, each with an umbilical tower. These would move to and from two permanent launch sites and a weatherproof launch preparation checkout and assembly building.

It is concluded that the Nova-class, six-to-12,000,060-1b-thrust vehicles are entirely feasible in many of the configurations considered, and that they could be in operational status by early 1965.

Pacing items in the development schedule would be:

- 1. Construction of the final assembly and launch complex.
- 2. Engineering and fabrication of the airframe.

(A major portion of Report No. TP 64--7 FPO 61-2 has been ignored in this abstract, as it is considered irrelevant to the present study.)

V. An Orbital Control Process for a 24-Hour Communication Satellite, NASA MEMORANDUM RM-2809, October 1961

This memorandum is concerned with the development of a guidance or orbital control process particularly applicable for use with a 24-hour communication satellite.

The desired orbit for the satellite considered in this study is a circular, equatorial orbit with a period such that the satellite remains above a specified point on the equator.

The memorandum is not concerned with the ascent trajectory phase of the problem. The assumption is made that a satellite has been injected into orbit approximating that of the reference orbit.

It is anticipated that the main burden of tracking, establishing errors in orbital movement, and computing corrective measures will be borne by ground stations rather than by instruments in the satellite.



The first objective of the guidance process is to move a satellite into the desired reference point after it has been injected into orbit. Next, it may be used as necessary to reduce errors arising from perturbations due to the gravitational accelerations of the sun, the moon, and the oblateness of the earth.

The memorandum describes the guidance process, the mathematical relationships involved, and some details of simulating its operation on a digital computer. The process itself depends on obtaining six or more independent observations, from one or more ground stations, of a satellite moving in an orbit.

These observations permit the calculation of orbital parameter errors. It is then possible to reduce these errors nearly to zero by applying corrective thrust to the vehicle.

W. A Study of the Feasibility of a Satellite Launching Ship (Classified), Chrysler Corporation, Huntsville, Alabama, 29 November 1961

This report discusses the feasibility of launching large solid propelled rockets on space as well as military missions from a modified AV-4.

Twenty presently available boosters were evaluated and, in the absence of clearly defined missions, a four-stage vehicle was chosen for a working model.

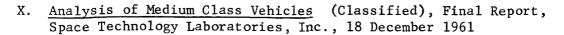
Individual studies were performed to investigate the ship's motion and launching kinetics and the feasibility of meeting fire control, guidance control, optical alignment, and prelaunch checkout requirements.

The modifications that would be necessary to the AV-4 to make it a self-contained operational unit are covered in detail by layout in addition to the text.

An investigation of the weight added for launching and tracking components reveals that normal ship's trim is established within acceptable limits as is the total displacement.

The report concludes that AV-4 is a suitable hull for modification and that the project appears to be technically feasible.

A recommendation was made that a more detailed investigation be conducted in all areas, and that the potential of the AGSL be weighed against firm missions that were being established by Space Technology Laboratories at that time (November 1961).



This study is an attempt to formulate the most economical method of conducting a series of approximately 200 unmanned space launchings with several different payloads and missions by the National Aeronautics and Space Administration during the next ten years.

The payload capabilities, launch base and operational requirements, parallel developments, and reliability considerations for 15 candidate launch vehicle assemblies (LVA) are considered in the study.

Two types of launch bases are considered:

- (1) Unprepared launching areas (such as, desert regions, remote islands, equatorial sites, and polar regions) may be utilized provided the boost vehicle and payloads are mobile and simple to operate.
- (2) Well-prepared launching bases such as the Atlantic Missile Range and the Pacific Missile Range may be necessary for the launching of space vehicles requiring more extensive ground facilities.

It is suggested that serious consideration be given to the use of mobile-launch vehicles, since the use of these avoids a certain amount of scheduling and other problems inherent in fixed launch sites.

Detailed overseas launch and track facility construction costs at either Kona Coast, Hawaii, or Belem, Brazil, are estimated at \$31,369,000 for the Atlas-Centaur launch vehicle and at \$43,303,000 for the Saturn C-1 vehicle.

The study concludes that the solid fuel vehicles can be more economically and efficiently assembled in a vertical position on the launch pad than in the hangar for transport to the pad; also, that either the solid fuel vehicles or the liquid fuel vehicles can be used with considerably lower cost than current vehicles provided that standardization of vehicles, payload, and techniques is accomplished.

(The major portion of the Final Report, Contract No. NAS8-8-2437, has been omitted from this abstract as being irrelevant to the present study.)



Y. <u>Study of Large Launch Vehicles Utilizing Solid Propellants</u>, Final Report, DOCUMENT NO. D2-20500-5, The Boeing Company, Seattle, Wash., 20 December 1961

The purpose of this study is to establish the important system parameters and operational problems of large launch vehicles utilizing solid-propellant motors, in one and two stages, with liquid propellant upper stages.

The study is presented in five volumes, and covers Phase I of a three-phase study.

Performance studies, cost estimates, support system requirements, development schedules, and reliability estimates are considered in the Phase I portion of the study in establishing the broad parameters on which the more detailed later phases could be based.

The characteristics of 22 vehicle configurations ranging between the extremes of stages consisting of one large solid fuel motor to stages consisting of clusters of 120-inch-diameter motors are considered. Payloads range from 50,000 to 350,000 lbs in a 307-nautical-mile orbit. The study vehicles consist of 11 two-stage vehicles with solid propellant boosters and 11 three-stage vehicles with solid propellant boosters and first stages.

Recommendations pertinent to launch site location include:

- 1. All land areas with a noise level of 125 decibels or over (5,700 to 19,800 feet from launch stand for vehicles studied) must be under control of the governing agency.
- 2. All launches should be made from shore out over the ocean.
- 3. All launch areas should be approximately equidistant from the ocean.
- 4. A flat, sea-level topography suitable for a canal network is needed. It is demonstrated that water transportation for the component parts of the missiles is both superior and less costly than land transportation.
- 5. Solid propellant manufacturing facilities for unitized configurations should be located adjacent to the assembly and launch facilities. Segmented motor production may be located adjacent to the assembly and launch operations or anywhere along a connecting inland waterway.

- 6. Layouts should be so arranged as to utilize both the minimum amount of ocean frontage and total acreage.
- 7. Range-safety equipment should be installed at the launch complex or at an adjacent area. These items may include surveillance and tracking equipment, computing equipment, optical tracking equipment, television cameras, and dual-command destruct transmitters.
- 8. The assembling of the vehicles should be near the launch site, but separated from it.
- 9. Assembly-line techniques and waterborne transportation should be used in the manufacture of all large components.

(A major portion of Document No. D2-2-500-5 is excluded from this abstract as being irrelevant to the present study.)

Z. On Applications of the Satellite Vehicle, JET PROPULSION, The American Rocket Society, Inc., New York. Author: R. P. Haviland (May 1956)

The purpose of this article is to discuss various applications of artificial satellites.

The article utilizes both maps and mathematical tables, as well as the usual graphs, in its presentation. It begins with a consideration of the geometrical situation of an orbiting satellite, stating that the computations are made for ideal conditions (that is, perfectly circular orbits, etc.). It notes that in actual practice the deviations from this should be slight unless the error is not reasonably small.

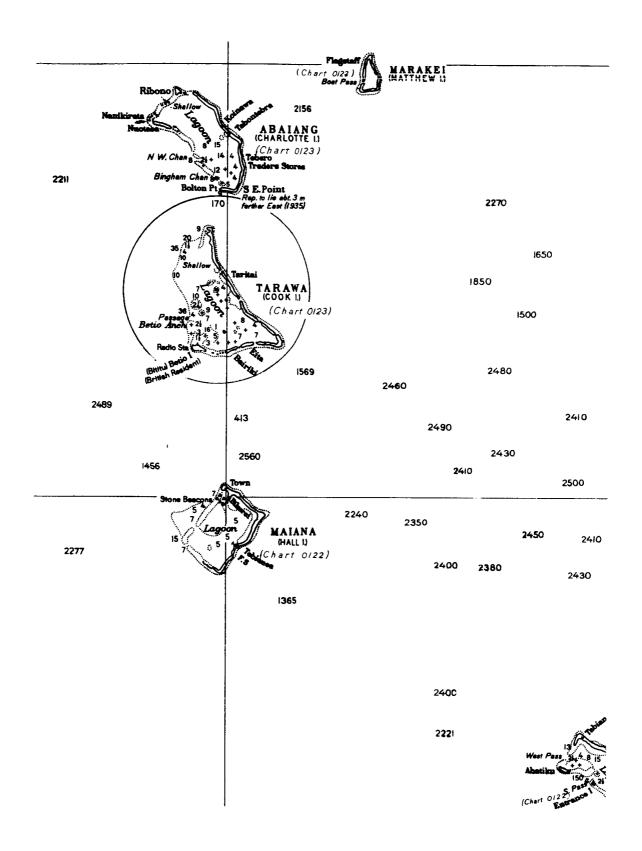
This paper notes the various ranges over which a satellite would be visible and, inversely, what areas of the earth would be visible from a satellite. A table is presented which presents figures ranging from altitudes of 57.3 miles to 22,300 miles. It is pointed out that these are maximum figures, and due to the fact that as the limit of observation (the "horizon", as seen from the satellite) is approached, much of the theoretically useful area would be rendered useless, whereupon the actual areas that could be considered useful might have to be reduced by a factor of nine.

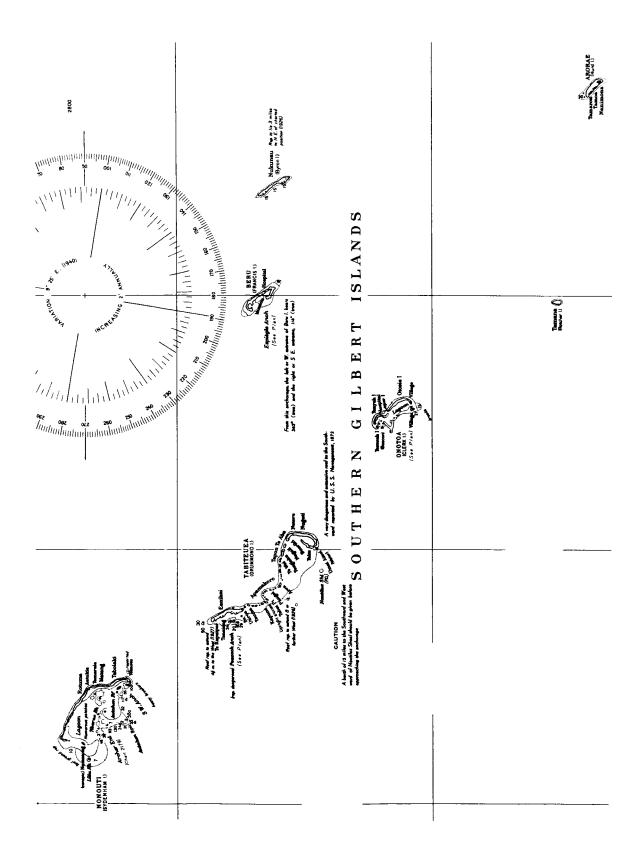
As an example, a satellite with an altitude of 620 miles above the surface of the earth in an equatorial orbit would have an extreme (theoretical) limit of the latitudes 30° N and 30° S; anything located north of the former or south of the latter would be invisible from the satellite, and vice versa. In actual practice, it is probable that the useful limit would be considerably less, due to the factors mentioned above.

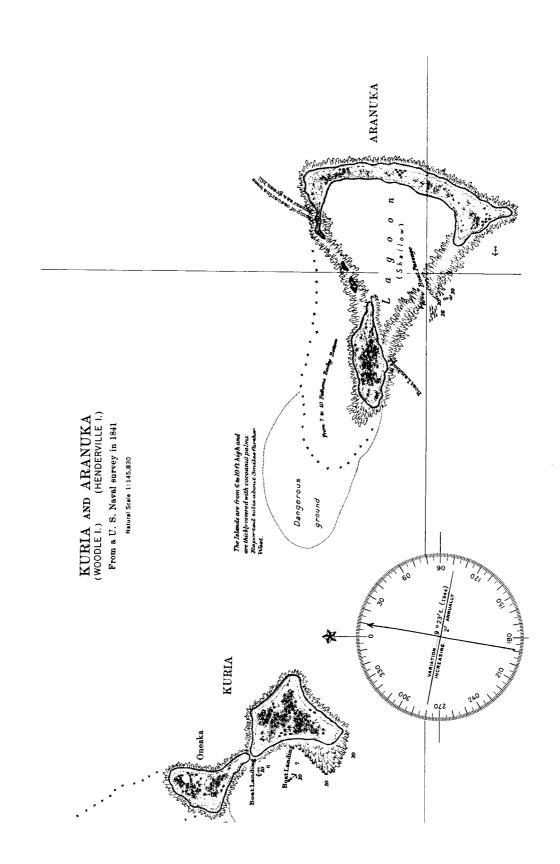
Careful map analysis demonstrates that for a scanning satellite, such as might be used for weather charting and forecasting, a polar orbit or one that is inclined is desirable.

(The paper examines particular uses of artificial satellites in the areas of mapping and cartography, communications, and weather charting and forecasting. The details have been omitted as of no relevance to this study.)

APPENDIX A. SELECTED MAPS

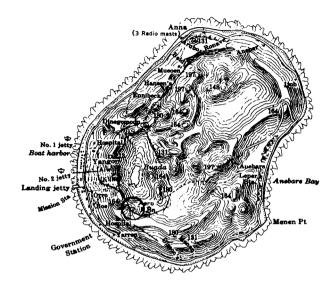




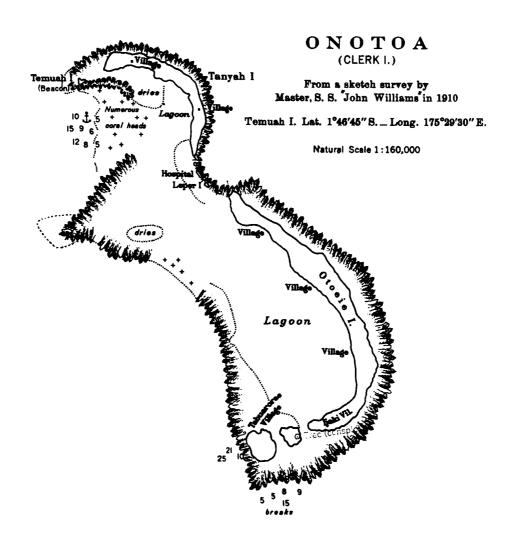


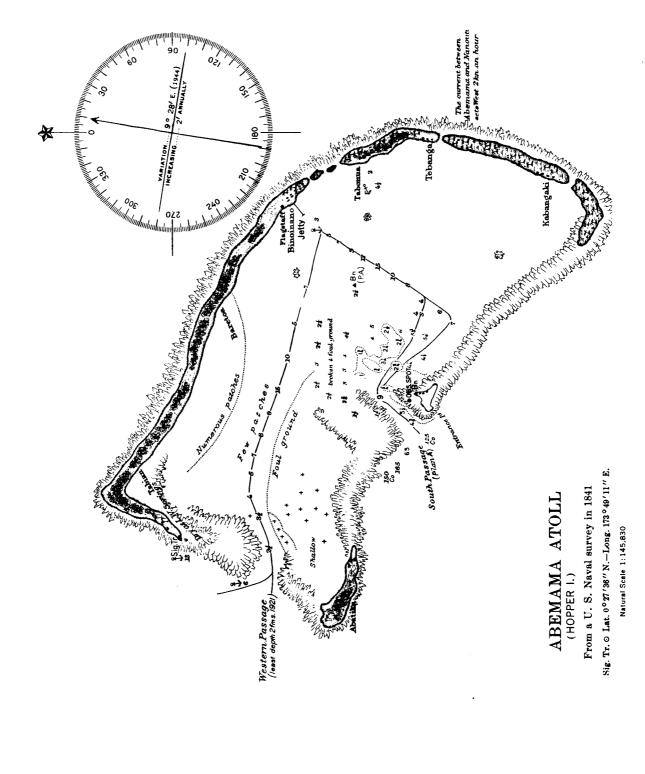
NAURU ISLAND

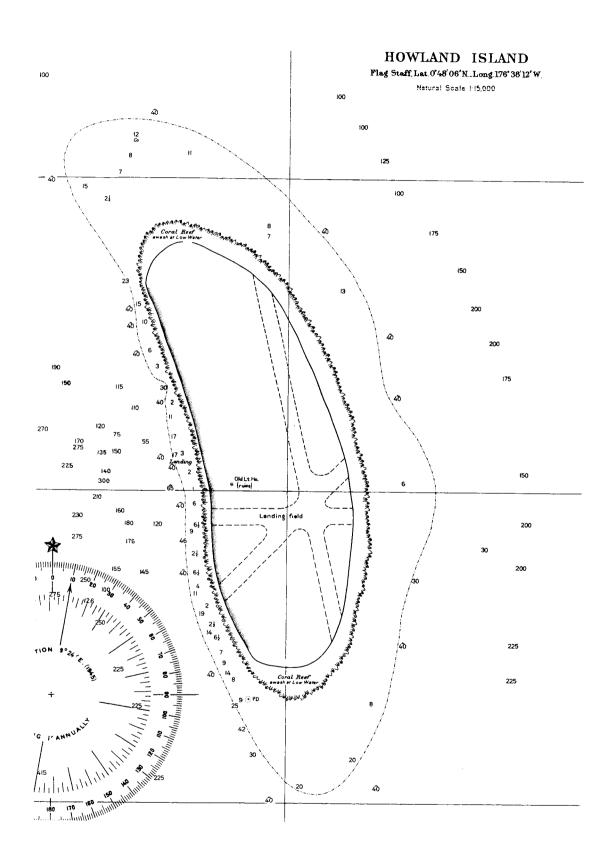
Natural Scale 1:76,130

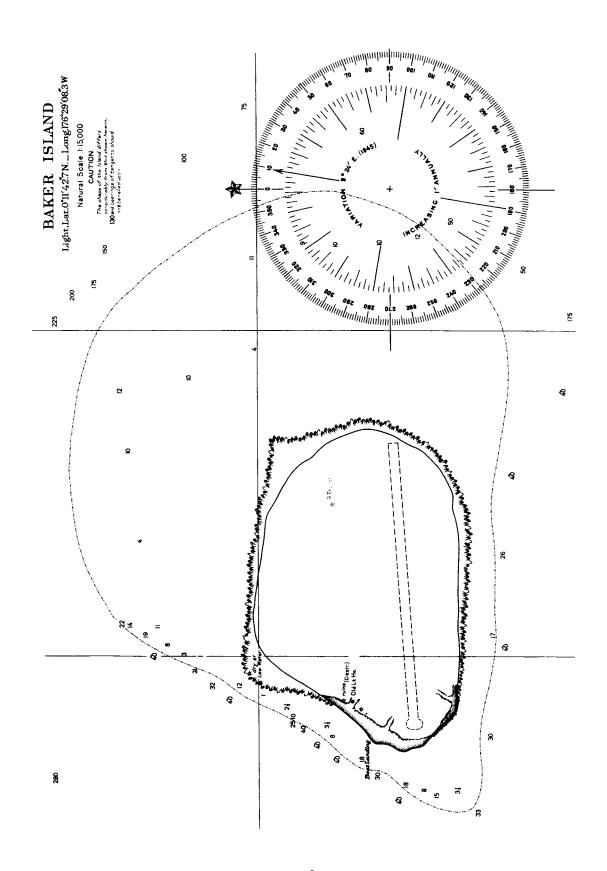


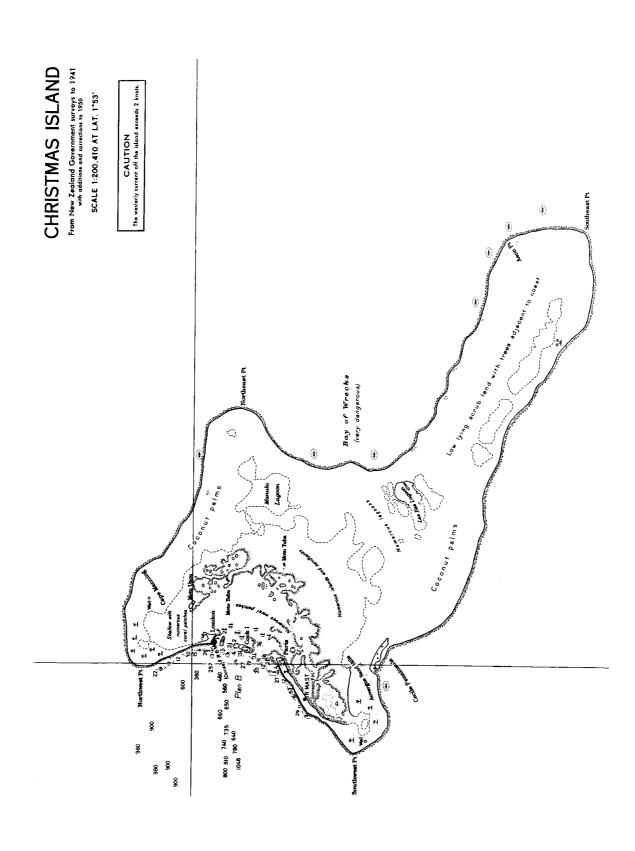
OCEAN ISLAND

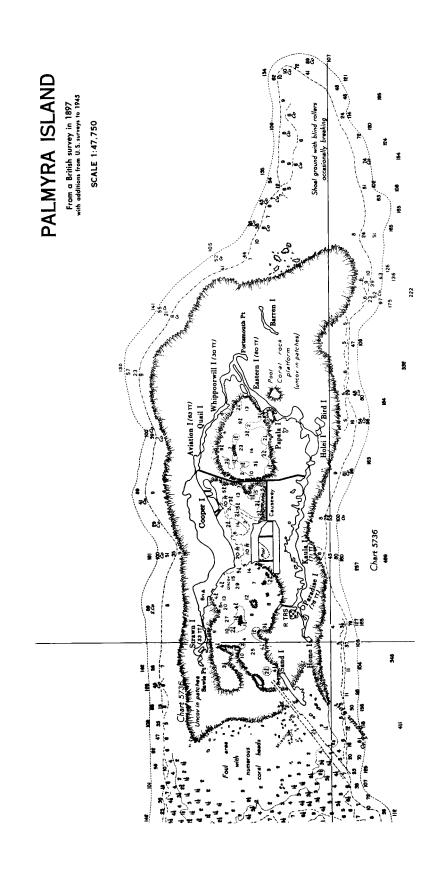


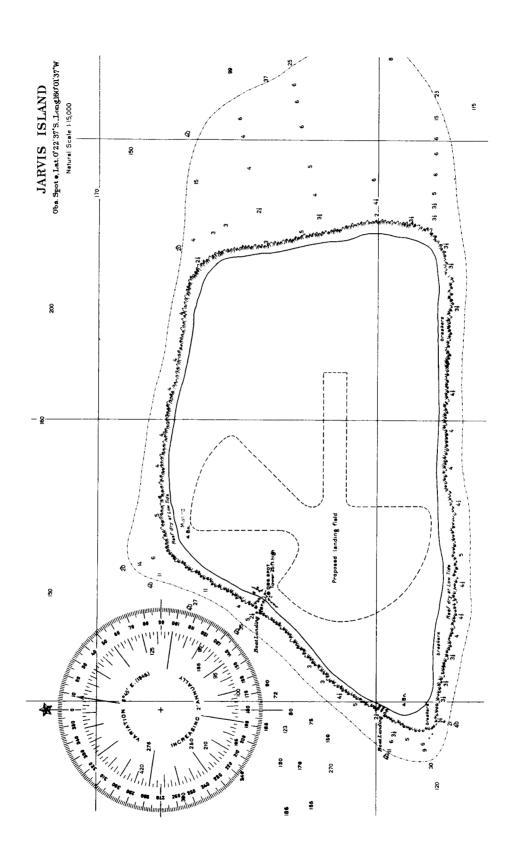


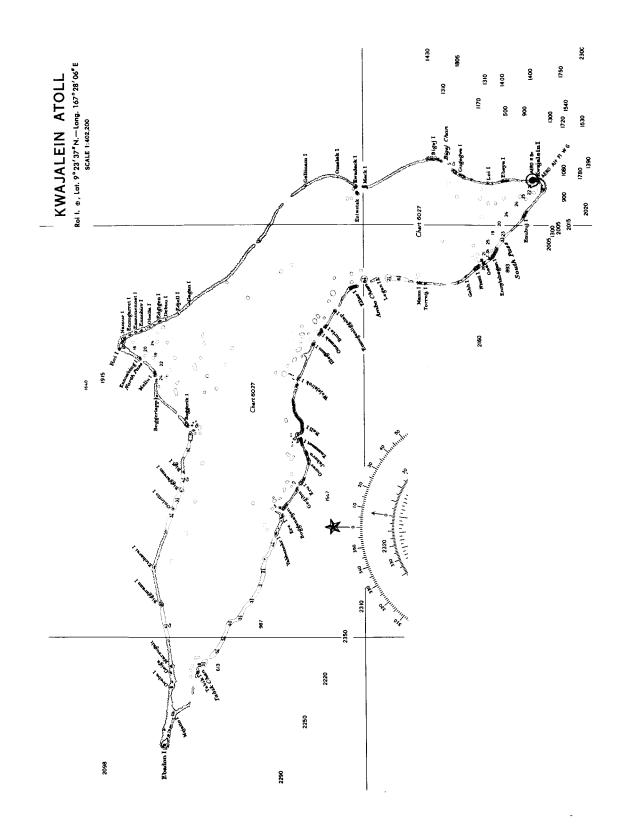


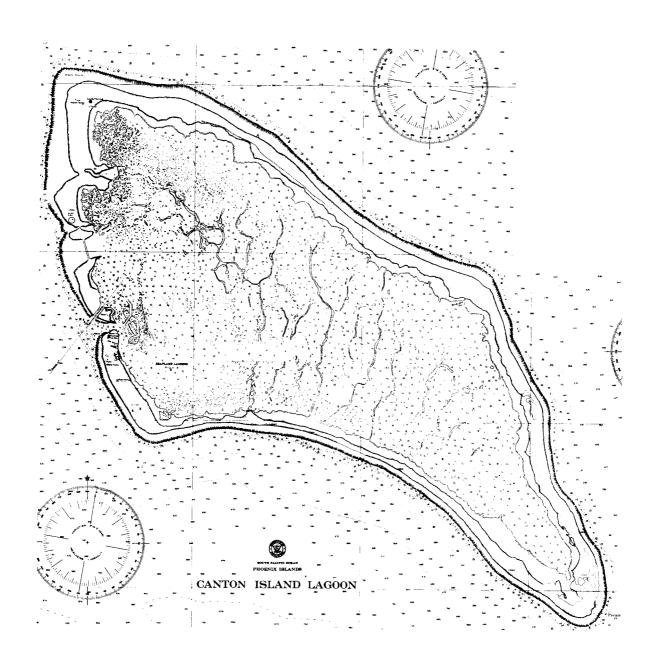


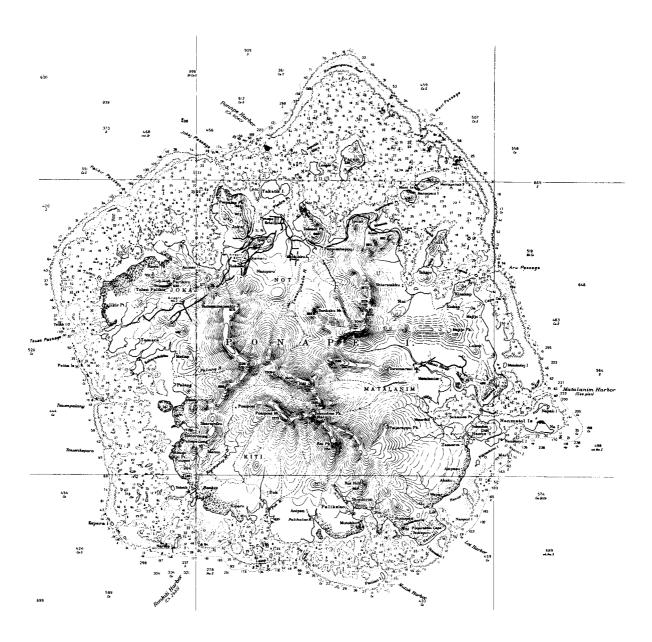




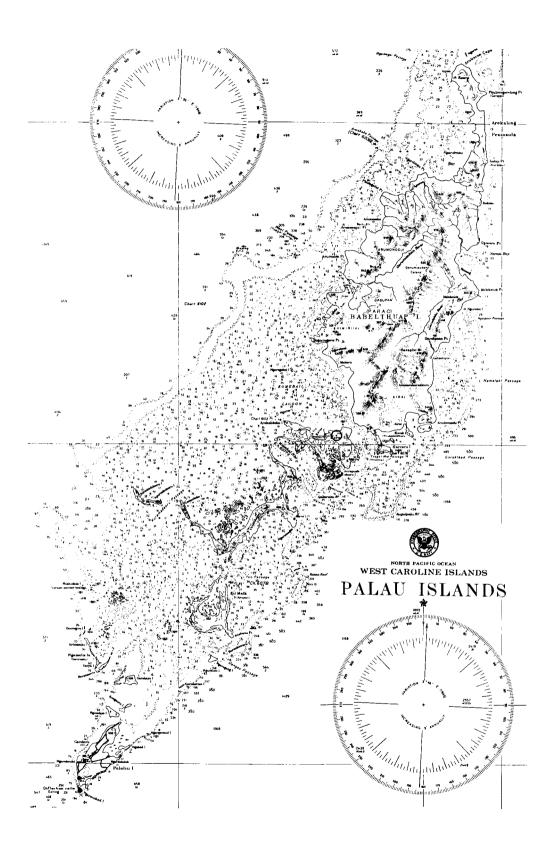


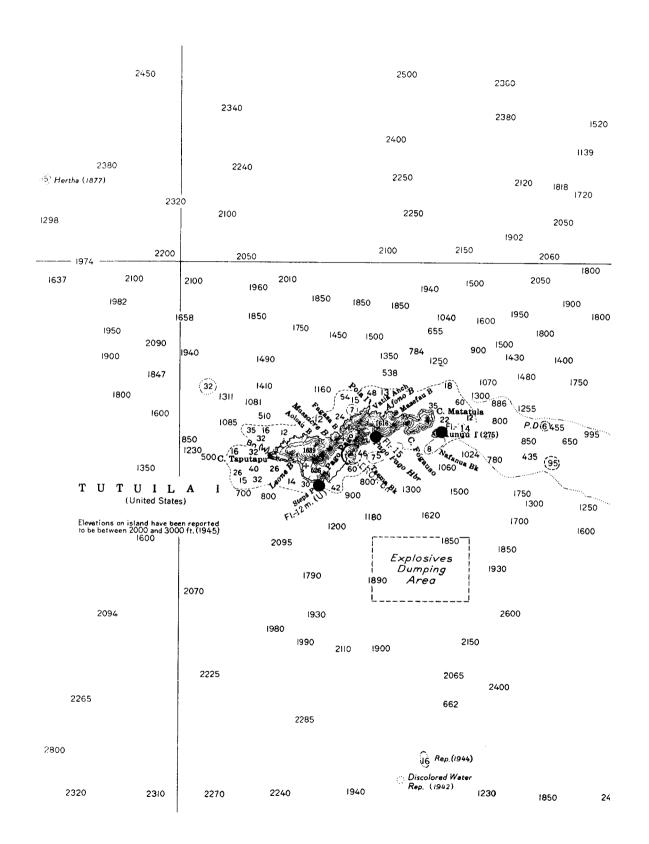












WASHINGTON ISLAND From U.S. Navy surveys in 1874

SCALE 1:36,630

